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UNIVERSITY OF MALAYA, SINGAPORE.

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WIND AND DRIFT CURRENTS IN THE SOUTH CHINA SEA

By W. L. DALE

The South China Sea occupies the largest of twenty-six basins on a partly submerged land-bridge between Asia and Australia. The bridge is bounded on the east by the Philippine Deep (34,125 ft.) and the Pacific Ocean, on the west by the Sunda Trench (24,230 ft.) and the Indian Ocean. Stretching diagonally across this bridge, and reaching from one side nearly to the other, the South China Sea provides the only direct sea connection between the North Pacific and Indian Oceans. In this respect it resembles the Mediterranean Sea which, with the Red Sea, links the North Atlantic and Indian Oceans. The South China Sea is 2,000 miles in length, with a maximum depth of 17,784 ft. and a sea-level area of 895,000 sq. miles. In average depth it is superior, and in area slightly inferior, to the Mediterranean Sea, but in length the two seas are similar. The South China Sea is of considerable importance in that many of the main shipping lanes between Western and Far Eastern countries, pass through it; the presence of such a large body of water exercises a considerable influence upon the the climate of the surrounding countries of South-East Asia whose populations use its valuable fishing grounds.

The purpose of this discussion is to examine the nature of, and relationship between, the winds and surface water movements of the South China Sea. A series of monthly charts have been prepared as the basis for this study. Each monthly chart contains four sections. Those marked "A" show the direction and constancy of the prevailing wind. They have been prepared from climatological tables compiled by British and Dutch authorities.[1] The construction of these sections may be illustrated from Table 1.[2] If, for example, the figures for August are examined it is evident that the south-west sector has the highest percentage of wind

TABLE 1: MONTHLY WIND DIRECTION AT PRATAS ISLAND, 20° 42'N., 116° 43'E.

MONTH	NUMBER OF DAYS PER 100 ON WHICH PARTICULAR WINDS MAY BE EXPECTED								
	N	NE	E	SE	S	SW	W	NW	CALM
JANUARY	9	69	12	2	1	0	0	1	6
FEBRUARY	9	62	12	2	2	1	1	0	12
MARCH	8	56	17	4	3	1	0	0	11
APRIL	4	30	27	10	10	3	1	1	15
MAY	6	21	14	6	13	15	4	2	19
JUNE	2	9	8	11	30	24	6	2	8
JULY	5	3	9	11	26	21	4	2	19
AUGUST	3	5	8	8	14	34	12	3	13
SEPTEMBER	3	32	19	11	5	5	4	3	18
OCTOBER	5	83	7	1	0	0	1	1	3
NOVEMBER	7	76	13	1	1	0	0	0	3
DECEMBER	7	73	14	1	1	0	0	0	4

1. Superior numbers in the text refer to titles in the bibliography on p. 31.

Fig. 1. South China Sea: key map.

observations for that month. The term sector as used in this particular connection includes any three adjacent compass directions, and is therefore slightly larger than a quadrant. Thus the three percentages 14, 34 and 12 are included in the south-west sector, and are employed in the construction of a parallelogram of forces from which the resultant wind direction for the south-west sector is obtained. This is taken as the mean direction of the prevailing wind. The sum of the three percentages is adopted as a measure of the wind's constancy of direction, which in this instance is 60 per cent. On the charts wind direction is shown by means of arrows, and the constancy of direction is indicated by the thickness of the arrow shaft, as explained in the legend. Thus on chart 11A the arrow plotted for Pratas Island signifies that the mean direction of the prevailing wind in August is approximately south-west, and that for between 50 and 74 per cent of the days of the month the winds tend to conform to this general direction. From the figures for October, in the same table, it is clear that the

prevailing wind in that month is north-easterly and its constancy of direction 95 per cent. The arrow plotted on chart 1A for Pratas Island runs from north-east to south-west and the thickness of its shaft indicates a constancy of between 75 and 100 per cent. This procedure has been repeated for fifteen coastal stations and fifteen five degree squares of the South China and Java Seas for every month of the year.

The "B" sections of the charts show air-stream boundaries and air-stream lines. The placing of the air-stream boundaries is similar to that suggested by Watts.[3] The boundaries are constantly moving and their representation here conveys only a probable mean position for each month. The air-stream lines are drawn from the information shown on the "A" sections of the charts, not from vector means. In view of the strong seasonal character of the winds over the South China Sea, air-stream lines based upon the mean direction of the prevailing wind give a more realistic impression of the actual winds experienced than those based upon a mean of all winds from all directions.

The "C" sections are drawn from charts published by the Marine Branch of the Meteorological Office,[4] the Hydrographic Department of the Admiralty[5] and by the Hydrographic Office of the United States Navy.[6] Symbols, similar to those used in the "A" sections for winds, here signify the mean resultant direction and constancy of direction of the surface currents. The procedure in preparing these charts is to divide the Sea into areas of 2° of latitude by 4° of longitude. The observations within these areas are totalled in successive 90° sectors around the whole compass, each sector being displaced 15° from its predecessor. The mid-direction of the sector containing the largest number of observations is the direction on which the arrows are plotted. The constancy of the predominant current direction is calculated in the same way as for the winds. The figures against the butts of the arrows give the average rate, in miles per day, of all currents observed flowing within 45° on either side of the direction shown on the chart. Thus these charts show the direction and average rate of current chiefly recorded in any area. The degree of probability that the current shown on any chart will be the one experienced in day to day navigation varies considerably in different areas, depending on the constancy of the current. When the constancy exceeds 50 per cent the predominant direction, or one very close to it, is that most likely to be experienced on any given occasion, that is, it will more probably occur than a current in any other direction. This probability is still greater if the constancy exceeds 74 per cent. Where the constancy falls below 50 per cent the degree of variability is such that no direction can be singled out as the most likely one on any given occasion. It seems worthwhile to show a predominant current in such an area since more currents will flow in that direction than in any other single direction. However, in such an area the total number of currents flowing in all other directions added together will exceed the number flowing in the predominant direction.

Sections marked "D" show the directions in which floating objects may be expected to move over a period of time. The same sources have been used in the preparation of these as for those marked "C".

Before proceeding to a detailed study of the South China Sea area, we should consider in general the winds and currents of this part of the world. The winds are related to one or other of nine air-streams which converge over South-East Asia during the course of a year. These air-streams come from three main directions and give rise to the pattern of air-stream boundaries illustrated in Fig. 2. The story of the winds of the South China Sea is one of advance and retreat by

the air-streams in each of the three sectors. During the north-east monsoon (northern winter) the air-streams of the N.E. Sector advance southwards over the sea pushing the air-stream boundaries in front of them. During the south-west monsoon (northern summer) air-streams from the South and West Sectors reverse the process. During the height of both seasons winds from the West Sector succeed in forcing their way between the winds of the other two Sectors so as to eliminate the Combined Air-Stream Boundary from the South China Sea area. A full treatment of this subject has been presented by Watts.[3]

The currents of the western North Pacific adhere to a fairly stable pattern throughout the year. The South Equatorial Current strikes the east coast of the Philippine Islands south of lat. 5°N. Between lat. 5°N and 10°N a narrow Equatorial Counter-current may be detected. From lat. 10°N to 20°N the broad North Equatorial Current approaches the Philippines bringing to Eastern Asia its main supply of warm water. This current is deflected northwards by the islands of Luzon and Formosa, and becomes the Kuro Shiwo (Kurosio) which sets

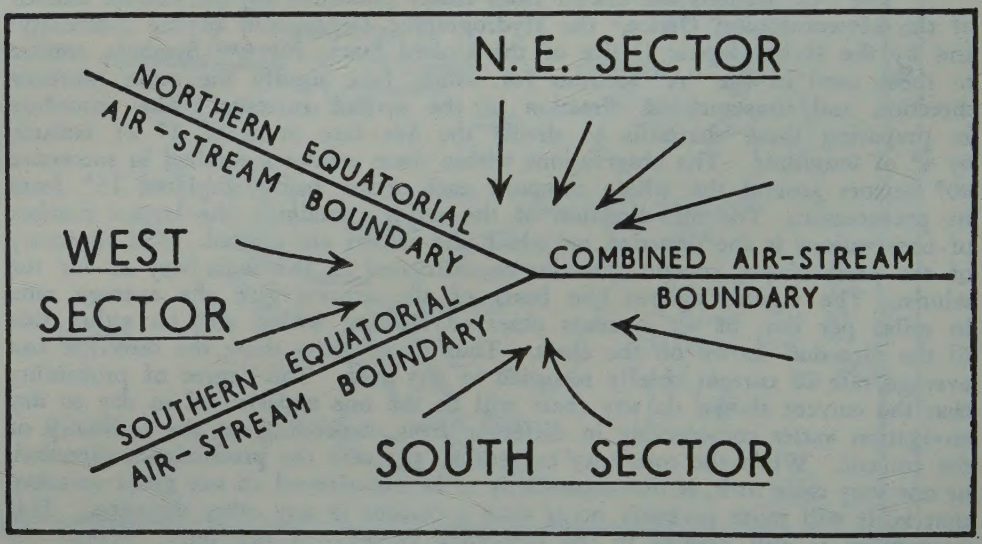

Fig. 2. Air-Stream Boundaries of South-East Asia.

to the north-east at a rate of between 24 and 72 miles per day, and has a width of 60 to 100 miles. East of Japan and north of lat. 35°N (where it is known as the Japan Current) it joins the North Pacific Current. Between the Asiatic mainland and this rigid system of circulation in the western North Pacific are eight large semi-enclosed seas, each with its own pattern of currents. The three most northerly seas (Bering Sea, Sea of Okhotsk and Sea of Japan), like the North Pacific, have more or less fixed systems of circulation. In the other five seas (Yellow, East China, South China, Sulu and Celebes Seas) the current pattern is constantly changing. In the South China Sea the system of currents is completely reversed twice a year. Although Luzon Strait faces the open ocean of the North Pacific with a width of more than 250 miles, and a sill depth of 7,500 ft. in places, it is several degrees too far north for the North Equatorial Current to penetrate the South China Sea and establish a permanent circulation. The disposition of the Philippines isolates, to a great extent, the South China Sea from the strong circulations of the western North Pacific. It is rather in the

monsoon winds which sweep across the Sea that an explanation may be found for its complicated water movements.

In our month by month analysis of wind and current conditions, October is adopted as the most suitable month with which to begin. As will be seen later, October is a transition period between monsoons for the central part of the Sea, and the pattern of air-stream boundaries illustrated in Fig. 2 is typical of the situation over the Sea at that time. Also it is at this time of the year that a south-setting drift makes its first appearance at all latitudes across the Sea. Thus the chart for October presents a characteristic patern of air-stream boundaries; it depicts the retreat of one monsoon and the advance of another, as well as the start of one of the major drift currents of the South China Sea.

OCTOBER (Chart 1)

Winds

In October the disposition of the air-stream boundaries over the South China Sea is similar to that shown in Fig. 2. East of long. 110°E the Combined Air-Stream Boundary approximates in position to the tenth parallel, and separates the advancing north-easterlies from the retreating southerly winds. Westwards the Combined Air-Stream Boundary is replaced by Northern and Southern Equatorial Air-Stream Boundaries which separate the retreating south-westerlies from the north-easterlies and southerlies respectively. North of lat. 20°N the north-easterlies attain a speed of Beaufort Force 4 to 7 (see Appendix, p. 30) for at least sixty per cent of the days of the month, and gales (Force 8 to 12) may be experienced for 9 per cent of the days of the month. In direction they show a constancy of at least 75 per cent. Between lat. 20°N and the air-stream boundary wind speeds vary between Forces 1 and 7, and their constancy of direction decreases as the discontinuity is approached. In both the South and West Sectors winds are light and variable. From 9 to 15 per cent of the days of the month experience calms.

Currents

The surface water movements in the Sea in October are characterized by a south-setting drift current on the west, and a slow and variable flow on the east. Beneath the strong and persistent north-easterlies a well defined drift enters the Sea through Formosa Strait, and flows close to the coast of the Asiatic mainland. The speed of this drift averages 20 miles per day, its constancy of direction is everywhere greater than 50 per cent and in places it exceeds 75 per cent. The close similarity between the direction and constancy of both the winds and the drift suggests that the momentum of the drift is derived from the stress exerted by the north-easterlies upon the sea below. The drift continues its course southwards along the coast of Annam, where its speed increases to 33 miles per day, and thence across the Sunda Shelf towards the Java Sea. Between Singapore and Borneo the drift bifurcates, one branch setting to the east at 10 miles per day, the other proceeding to the Java Sea at 3 miles per day. The east going branch would appear to be assisted, if not partly caused by, the south-westerly winds which prevail over this part of the Sea. The slowing down of the drift in the Gaspar and Karimata Straits is to be expected beneath moderately persistent south-easterly winds coming from the Java Sea. The establishment of a strong inflow of water in the north and an obstruction in the south tends to convert the South China Sea into a large counter-clockwise gyral whose circulation is largely maintained by the tangential disposition of the winds in the north and south. Large internal eddies occur within this gyral in October, but as the month progresses these disappear leaving a simpler pattern of circulation throughout the

Sea. During the early part of the month an east-setting drift maintains a steady transfer of water to the Sulu Sea. Later in the month the replacement of the south-westerlies by the north-easterlies is accompanied by a considerable reduction in the amount of overflow into the Sulu Sea.

NOVEMBER (Chart 2)

Winds

During November westerly winds succeed in penetrating eastwards across the Gaspar and Karimata Straits, thereby establishing a 500-mile wide corridor between the air-streams from the North-East and South Sectors. The North Equatorial Air-Stream Boundary, between the westerlies and the advancing north-easterlies, runs parallel with the east coast of Malaya and the north-west coast of Borneo. The Southern Equatorial Air-Stream Boundary, separating the westerlies from the southerlies is found in the vicinity of lat. 5°S. North-easterly winds prevail over most of the Sea. Their strength north of lat. 15°N varies between Forces 4 and 7. Gales are frequent over the open sea. For example, 17 per cent of the days record winds of gale force in the Luzon Strait. South of lat.15°N wind speeds and their constancy of direction show a marked decrease.

Currents

The counter-clockwise gyral initiated in October persists throughout November, but its form is simpler due to the disappearance of the large internal eddies. The gyral is asymmetrical, being elongated in a north-south direction. It has a broad (up to 500 miles), slow-moving (9 to 15 miles per day) eastern limb, and a narrow (less than 100 miles in places) but swifter (up to 40 miles per day) western limb. The south-setting western limb is a part of the main drift which enters the Sea through Formosa Strait in the north and flows into the Java Sea in the south. This drift acquires an average speed of 21 miles per day and its constancy of direction seldom falls below 75 per cent between Hong Kong and the Anambas Islands. In November drift speeds are particularly high where the winds and drifts have approximately the same direction, and low where they are in opposition. From November until March currents conveying water to the South China Sea come from the north and east through three main channels: (1) from the East China Sea via Formosa Strait; (2) from the western North Pacific via Luzon Strait; and (3) from the Sulu and Sibuyan Seas via the many passages between Luzon and Borneo. Overflow takes place to the south via the Gaspar and Karimata Straits into the Java Sea, and west via Malacca Strait into the Indian Ocean. Malacca Strait serves as a permanent overflow channel to the Sea.

DECEMBER (Chart 3)

Winds

The Northern Air-Stream Boundary now lies close to, or astride of, the equator. Strong north-easterlies, of Force 4 to 7, and a constancy of direction greater than 75 per cent, prevail over the Sea north of the fifth parallel. Gales are frequently experienced over the open sea, even at low latitudes. Over the Java Sea westerly winds of Force 3 and a constancy of more than 50 per cent are characteristic. They are, however, sometimes replaced for short periods by temporary advances of the north-easterlies, thus establishing a Combined Air-Stream Boundary with the southerlies over Java.

Currents

The gyral that characterized the Sea in October and November is by now considerably modified. Its western limb remains as the main drift setting south at an average speed of 20 miles per day and with a constancy of direction of

75 per cent or more. The eastern limb is replaced by a general surge of water westwards feeding the main drift. The disturbance of the gyral appears to reflect the increased strength and persistency of the north-easterlies resulting in a general flow of water from east to west in the east and central parts of the Sea.

JANUARY (Chart 4)

Winds

The only appreciable change in the winds in January is that north of the tenth parallel their strength weakens slightly, and south of this latitude it increases considerably. During most of this month the Northern Equatorial Air-Stream Boundary is pushed beyond the South China Sea into the Java Sea.

Currents

Surface water movements are similar to those of the previous month, except that the westward surge in the eastern part of the Sea is even more pronounced, and the average speed of the main drift decreases from 20 to 16 miles per day. The speed is considerably reduced in the north where the wind strength has weakened. On the other hand the drift shows a higher constancy of direction in the north in this month.

FEBRUARY (Chart 5)

Winds

Whilst the constancy of direction of the winds remains above 75 per cent over the entire Sea, their strength weakens considerably in February. Winds of gale force are seldom experienced, and strengths of Force 4 to 7 are predominant only north of lat. 20°N. From lat. 20°N to 5°N wind strength varies between Forces 1 and 7. South of the fifth parallel more than 50 per cent of the days experience wind strengths of only Force 0 to 3. Another noticeable feature of the winds is their tendency to veer as the end of the month approaches.

Currents

The speed of the main south going drift decreases to 15 miles per day, and its constancy of direction falls below 75 per cent in several places. These traits in the drift currents seem to conform with the weakening of the winds above them.

MARCH (Chart 6)

Winds

Throughout March the north-easterlies continue to weaken, and south of lat. 7°N their constancy of direction falls below 75 per cent. Towards the end of the month the retreat of the north-east monsoon becomes apparent from a slight northward shift of the Northern Equatorial Air-Stream Boundary, and an increase in the percentage of calms observed south of the tenth parallel. For example the per cent of time calms may be expected over the sea off Condore Island increases from 4 in February to 21 in March.

Currents

As with the winds so with the currents, March is a month of considerable change. The south-setting drift on the western side of the Sea is now less well defined. Its constancy of direction nowhere reaches 75 per cent, and in places it falls below 50 per cent. Pronounced westward curves appear in the path of the main drift at the entrances to the Gulfs of Tonkin and Thailand. The veering of the north-easterlies might well account for such marked diversions of the drift into the mouths of these gulfs. The average speed of the drift is now only 14

miles per day, and its width is much reduced. The swiftest part of the drift from October to February occurs off the coast of Annam, but in March the maximum speed is experienced off the south coast of China where the north-easterlies are still strong and their direction approximately parallel with that of the drift below. Water movements throughout most of the Sea in March tend to become variable and uncertain. The general westward trend, however, is still discernible.

APRIL (Chart 7)

Winds

Whilst the north-easterlies still prevail over the Sea they continue to weaken and to veer. In most places their constancy of direction falls below 75 per cent, and in the south it is less than 50 per cent. South of the fifth parallel April is remarkable for its calm weather. Over the open sea 20 per cent of the days in the month experience a calm. At coastal stations the percentage is even higher. At Trengganu 28 per cent of the wind observations show a calm, whilst at Singapore the figure is 46 per cent. April is the month of transition between monsoons for the southern half of the South China Sea. The leading air-stream boundary of the north-easterlies begins to migrate northwards, whilst the westerlies withdraw to the north-west and are replaced by south-easterly winds from the Java Sea.

Currents

Surface water movements are highly irregular in April. The south-setting drift so well established on the western side of the Sea since October is now represented by a narrow sluggish drift south of lat. 10°N. Elsewhere the pattern of water movements seems to be that of a series of slow transitory circular drifts. A remarkable feature occurs in the Formosa Strait where a north-setting drift having a constancy of direction of over 75 per cent flows beneath winds which also show a constancy of more than 75 per cent but in the opposite direction. This might be due to the penetration of a branch of the north-setting Kuro Shiwo around the western side of Formosa at this time of the year.

During this month the Sea overflows through the Malacca, Gaspar, Karimata and Formosa Straits, and is replenished from the Sulu and Sibuyan Seas and by a branch of the Kuro Shiwo through Luzon Strait.

MAY (Chart 8)

Winds

The weakening of the north-east monsoon in April is followed by a marked retreat of the north-easterlies in May. At the same time southerly wind streams gather strength and constancy of direction, but the westerlies withdraw still further to the north-west. The resulting disposition of air-stream boundaries resembles that obtaining in October, when the north-east monsoon was advancing and the south-westerly monsoon retreating. A Combined Air-Stream Boundary now crosses the South China Sea in a north-west to south-east direction between latitudes 10° and 15°N. Westerlies prevail over Thailand and Indo-China giving rise to a North Equatorial Air-Stream Boundary south-west of the Gulf of Tonkin and a South Equatorial Air-Stream Boundary across the Gulf of Thailand and southern Indo-China. Although the constancy of direction of the prevailing winds remains between 50 and 75 per cent over most of the Sea wind speeds are low and the number of calm days higher than usual. May is the month of transition between monsoons over the northern part of the Sea.

Currents

The general south-to-north flow of light winds over the western part of the Sea is matched below by a sluggish north-setting drift. The direction of the drift is less well defined in the north than in the south. As in April, the north-going drift through Formosa Strait is in opposition to the winds above. The average speed of the drift on the western side of the Sea is 13 miles per day, but intervals of calm water, or even temporary local reversals in direction, are frequent. On the eastern side of the Formosa Strait the drift flows at 20 miles per day with a constancy of direction of 75 per cent. Over the eastern part of the South China Sea water movement is slow and variable. The general direction of the flow is from west to east. A series of small eddies occur in the Sea in this month but they appear to bear little relation to those observed in the previous month.

JUNE (Chart 9)

Winds

The north-east monsoon has withdrawn from the South China Sea by about mid-June. Air-streams from the south and south-west now converge over the Sea. Winds from the south form a South Equatorial Air-Stream Boundary with winds from the south-west in the vicinity of lat. 5°N. South-westerly air-streams from the Indian Ocean, after crossing the Malay Peninsula, tend to back and become southerly over the northern half of the South China Sea. Their constancy of direction exceeds 75 per cent on the west, but falls below that figure over the eastern side of the Sea. Wind speeds in the south-westerlies rarely exceed Force 7. In the southerlies speeds in excess of Beaufort Force 4 are infrequent.

Currents

A comparison of wind charts for June and January shows that wind directions in these two months differ by about 180 degrees. Similarly, if the current charts for the same two months are compared it will be seen that the directions of the surface water movements also differ by about 180 degrees over most of the South China Sea. In January north-easterly winds prevail over the Sea and a south-setting drift dominates the water movements. In June south-westerly winds pervail, and beneath them a drift setting north-east characterizes four-fifths of the Sea. The average speed of the drift in January is 16 miles per day to the south, in June it is 17 miles per day to the north. It is also evident that the intake of water in January comes from the east (East China Sea, the Pacific Ocean and the Sulu Sea), in June it comes from the south and east (Java and Sulu Seas). The overflow in January is to the Indian Ocean and Java, Sea, in June it is primarily to the Pacific Ocean.

JULY (Chart 10)

Winds

The general pattern of winds in July is similar to that for June. Wind strengths and constancy of direction, however, tend to increase. The southerly winds attain a strength of Force 4 to 7 in places over the open sea. The south-westerlies also increase in strength but not sufficiently to maintain the same degree of superiority over the southerlies that they had in June. This change in relative strengths accounts for the northward migration of the Southern Equatorial Air-Stream Boundary. Another change may be detected in the tendency for the winds over the central part of the Sea to veer, and for those in the north to back.

Currents

The broad north-setting drift so well established in June continues to flow without major change throughout July and August. Its speed tends to increase

slightly in the south and to decrease in the north. From late June until early September, when the south-west monsoon is at its height, the only intake of water comes from the Java Sea. The Straits of Malacca, Luzon and Formosa, together with the numerous passages into the Sulu and Sibuyan Seas, all serve as overflow channels.

AUGUST (Chart 11)

Winds

The wind system in August differs very little from that in July.

Currents

The main drift remains broad and steady in its set to the north-east. It seldom narrows to less than 200 miles, whilst in places it becomes as much as 500 miles.

SEPTEMBER (Chart 12)

Winds

In September the north-east monsoon re-appears. A gentle or moderate north-easterly breeze (Force 3 and 4), of moderate constancy (50 to 74 per cent) invades the northern part of the Sea and pushes the Northern Equatorial Air-Stream Boundary southwards in front of it. South of lat. 15°N a gentle south-westerly or southerly breeze (Force 3) represents the dying south-west monsoon. Although the south-west monsoon winds are weak their constancy of direction remains high, especially in the Gulf of Thailand and over the open sea between Indo-China and British North Borneo. The Southern Equatorial Air-Stream Boundary between the south-westerlies and the southerlies lies between Singapore and Palawan Islands.

Currents

Changes in the wind regime over the Sea in September are accompanied by prominent alterations in the pattern of surface water circulation. Instead of the north-setting drift, so well developed throughout June, July and August, a system of three gyrals may be distinguished. These appear to be forerunners of the gyral type of circulation so characteristic of the Sea in October and November. A large eccentric counter-clockwise circulation occupies the northern half of the Sea. A smaller irregular clockwise circulation occurs between Borneo and the Asiatic mainland. The third gyral consists of a small counter-clockwise movement south of the equator between Borneo and Sumatra. An outstanding feature of conditions in September is the similarity in direction and constancy of both the winds and the currents south of Cape St. Jacques. The winds there are south-westerly with a constancy of direction greater than 75 per cent. The currents in the Sea below set to the north-east or east, also with a constancy of more than 75 per cent. From sections C and D it would appear that both the northern and the central gyrals receive their initial impetus from these winds. The increasing stress of the north-easterlies over the northern part of the Sea, together with their tendency to resist overflow through the Luzon and Formosa Straits, seems to account for the counter-clockwise deflection of the waters north of lat. 17°N. The configuration of the coastlines of South China and Indo-China helps to complete the circular motion of the waters in this part of the Sea. The circular path of the central gyral is further promoted by the coastline configuration of North Borneo. Some of the water, however, escapes from this system into the Sulu Sea. South of the equator the winds have a high constancy of direction but they are weak and seem unable to retain the north-setting south-west monsoon drift. The east-to-west drift of the southern limb of the central gyral may also provide an impediment to the northward set of waters from the Gaspar and Karimata Straits. A drift speed of three miles per day is characteristic in this part.

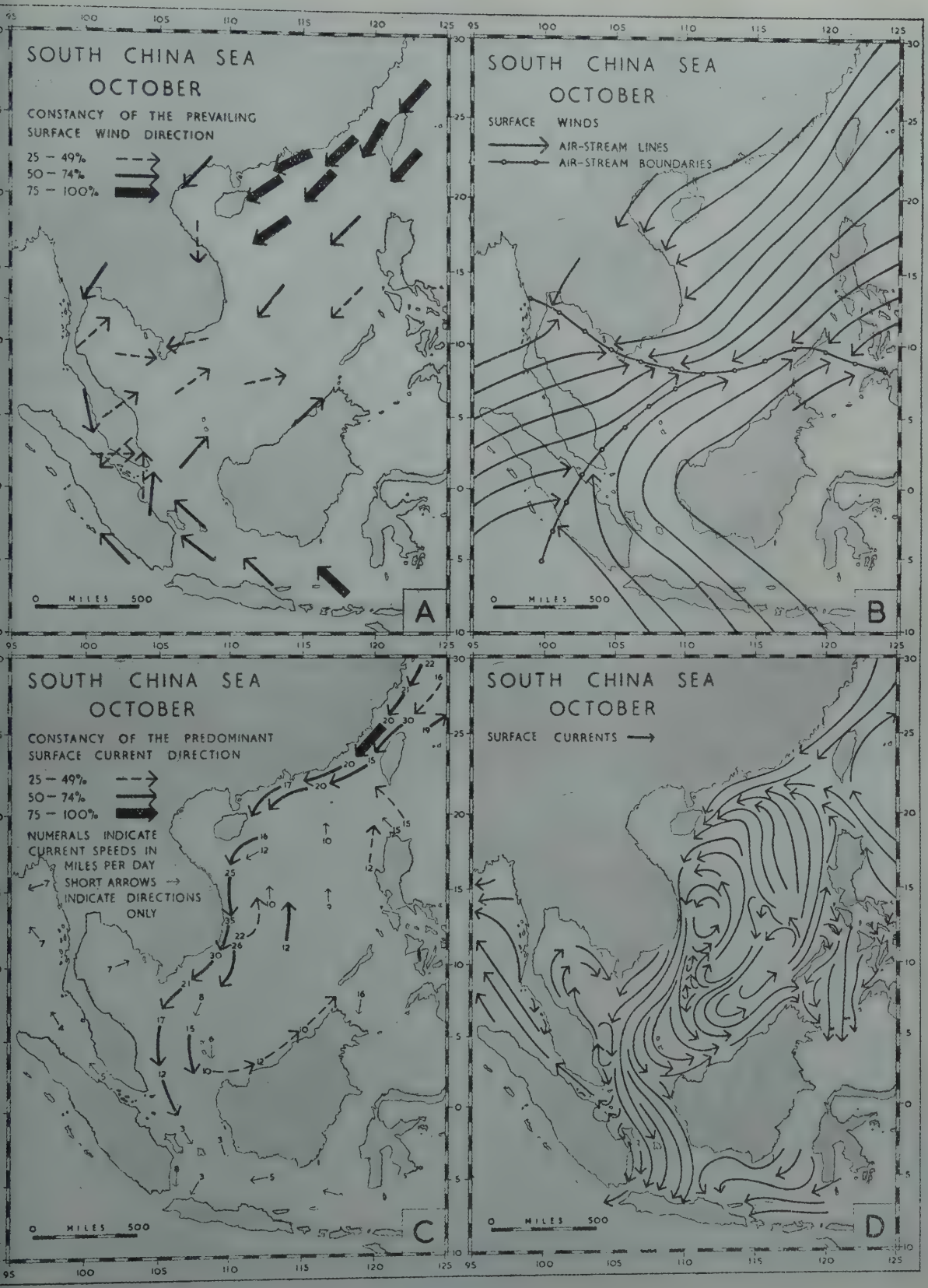
SOUTH CHINA SEA
OCTOBER
CONSTANCY OF THE PREVAILING SURFACE WIND DIRECTION
25 – 49%
50 – 74%
75 – 100%
0 MILES 500
A
SOUTH CHINA SEA
OCTOBER
SURFACE WINDS
AIR-STREAM LINES
AIR-STREAM BOUNDARIES
0 MILES 500
B
SOUTH CHINA SEA
OCTOBER
CONSTANCY OF THE PREDOMINANT SURFACE CURRENT DIRECTION
25 – 49%
50 – 74%
75 – 100%
NUMERALS INDICATE CURRENT SPEEDS IN MILES PER DAY
SHORT ARROWS → INDICATE DIRECTIONS ONLY
0 MILES 500
C
SOUTH CHINA SEA
OCTOBER
SURFACE CURRENTS →
0 MILES 500
D

Chart 1

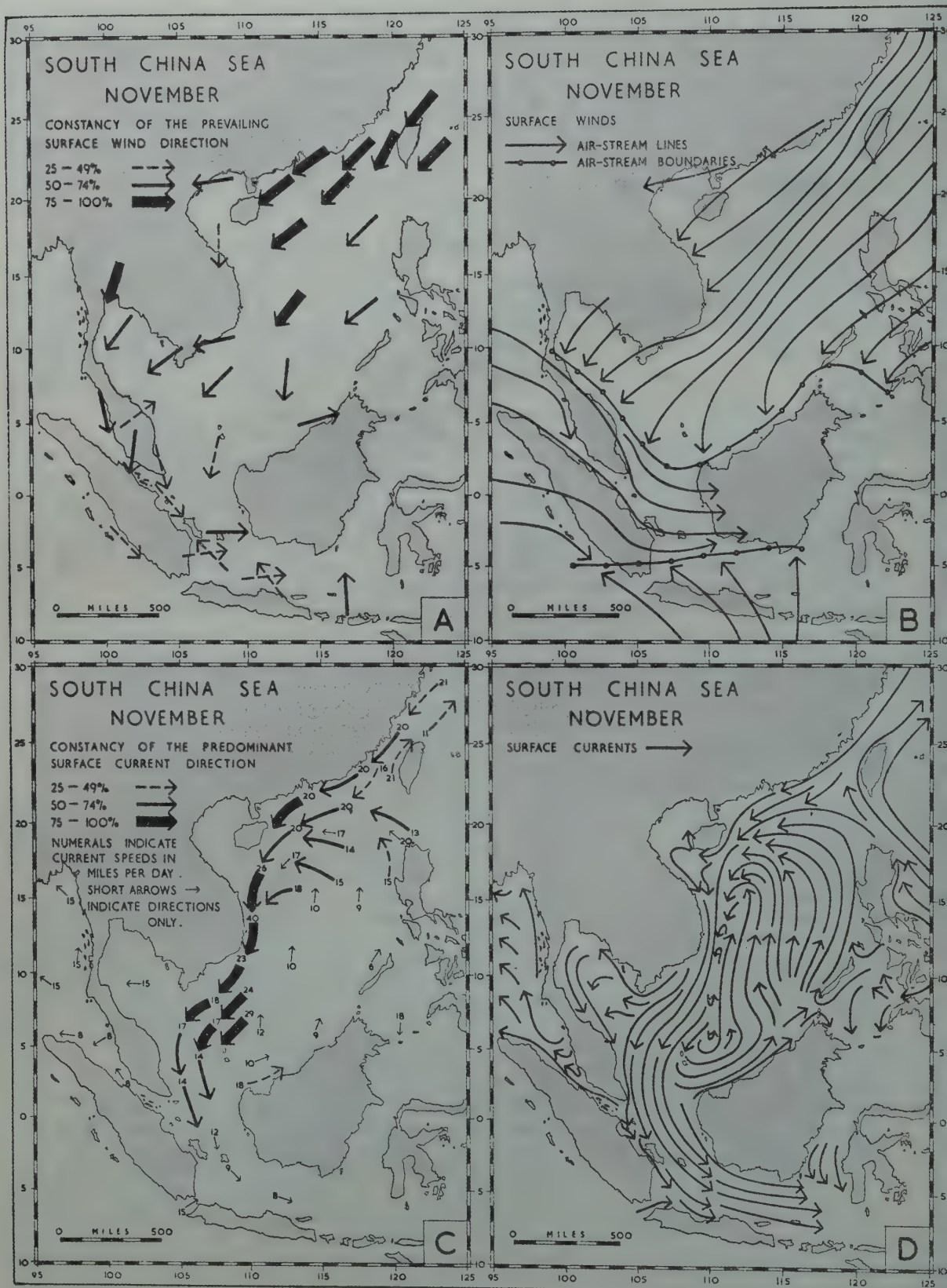
SOUTH CHINA SEA
NOVEMBER
CONSTANCY OF THE PREVAILING SURFACE WIND DIRECTION
25 – 49%
50 – 74%
75 – 100%
0 MILES 500
A
SOUTH CHINA SEA
NOVEMBER
SURFACE WINDS
AIR-STREAM LINES
AIR-STREAM BOUNDARIES
0 MILES 500
B
SOUTH CHINA SEA
NOVEMBER
CONSTANCY OF THE PREDOMINANT SURFACE CURRENT DIRECTION
25 – 49%
50 – 74%
75 – 100%
NUMERALS INDICATE CURRENT SPEEDS IN MILES PER DAY. SHORT ARROWS → INDICATE DIRECTIONS ONLY.
0 MILES 500
C
SOUTH CHINA SEA
NOVEMBER
SURFACE CURRENTS
0 MILES 500
D

Chart 2

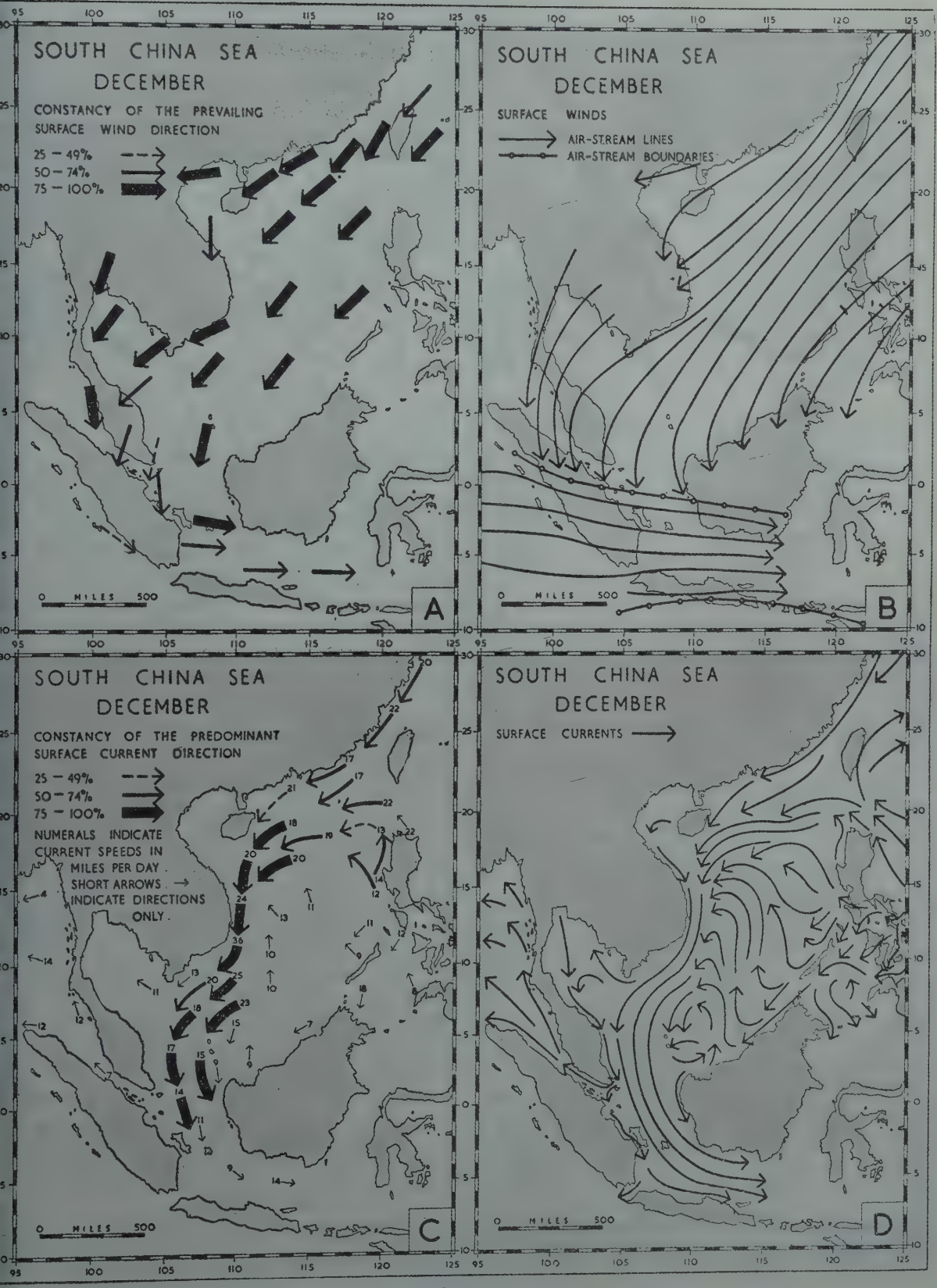
SOUTH CHINA SEA
DECEMBER
CONSTANCY OF THE PREVAILING SURFACE WIND DIRECTION
25 – 49%
50 – 74%
75 – 100%
0 MILES 500
A
SOUTH CHINA SEA
DECEMBER
SURFACE WINDS
AIR-STREAM LINES
AIR-STREAM BOUNDARIES
0 MILES 500
B
SOUTH CHINA SEA
DECEMBER
CONSTANCY OF THE PREDOMINANT SURFACE CURRENT DIRECTION
25 – 49%
50 – 74%
75 – 100%
NUMERALS INDICATE CURRENT SPEEDS IN MILES PER DAY. SHORT ARROWS → INDICATE DIRECTIONS ONLY.
0 MILES 500
C
SOUTH CHINA SEA
DECEMBER
SURFACE CURRENTS
0 MILES 500
D

Chart 3

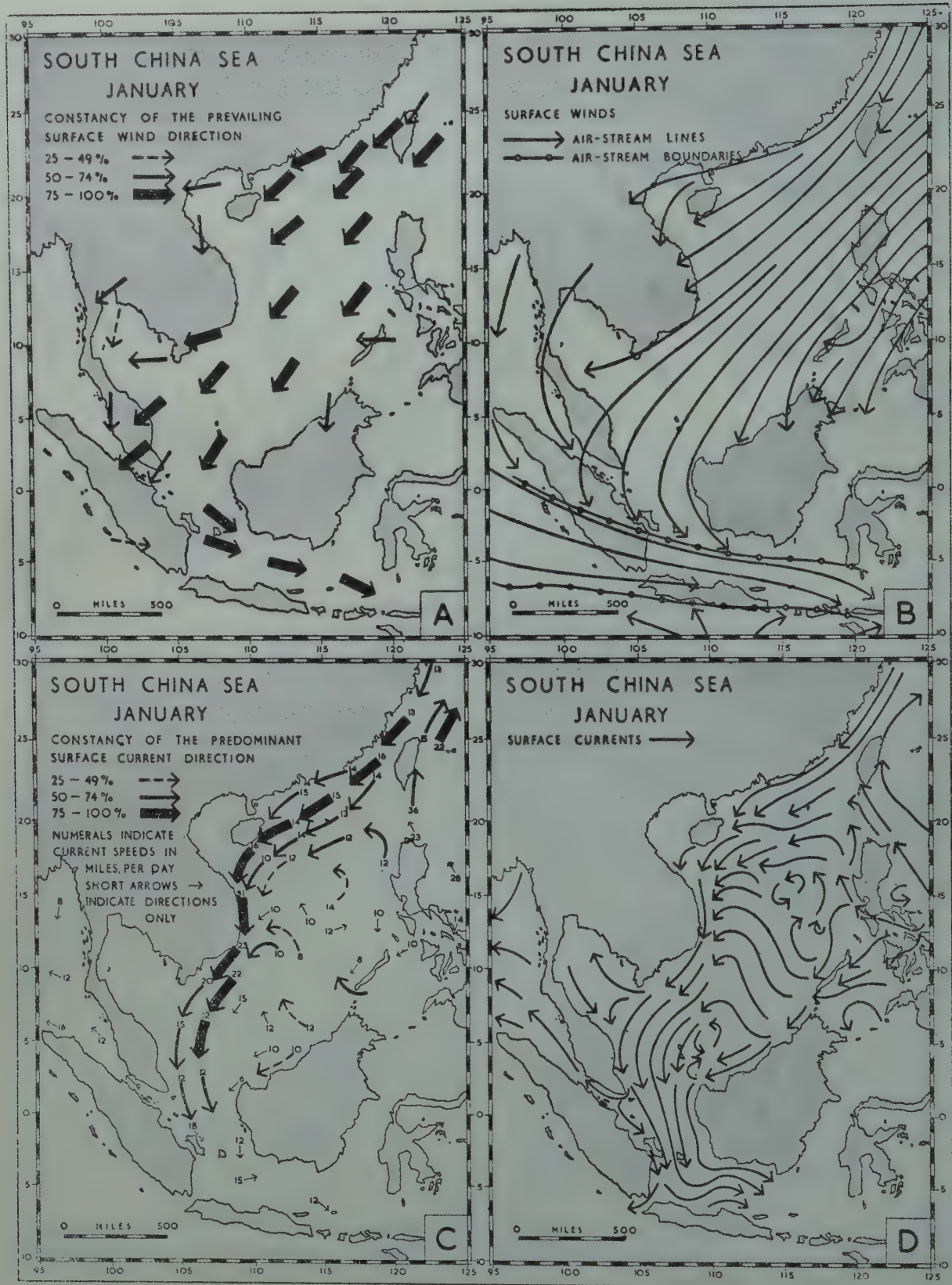
SOUTH CHINA SEA
JANUARY
CONSTANCY OF THE PREVAILING
SURFACE WIND DIRECTION
25 – 49 %
50 – 74 %
75 – 100 %
0 MILES 500
A
SOUTH CHINA SEA
JANUARY
SURFACE WINDS
AIR-STREAM LINES
AIR-STREAM BOUNDARIES
0 MILES 500
B
SOUTH CHINA SEA
JANUARY
CONSTANCY OF THE PREDOMINANT
SURFACE CURRENT DIRECTION
25 – 49 %
50 – 74 %
75 – 100 %
NUMERALS INDICATE
CURRENT SPEEDS IN
MILES PER DAY
SHORT ARROWS →
INDICATE DIRECTIONS
ONLY
0 MILES 500
C
SOUTH CHINA SEA
JANUARY
SURFACE CURRENTS →
0 MILES 500
D

Chart 4

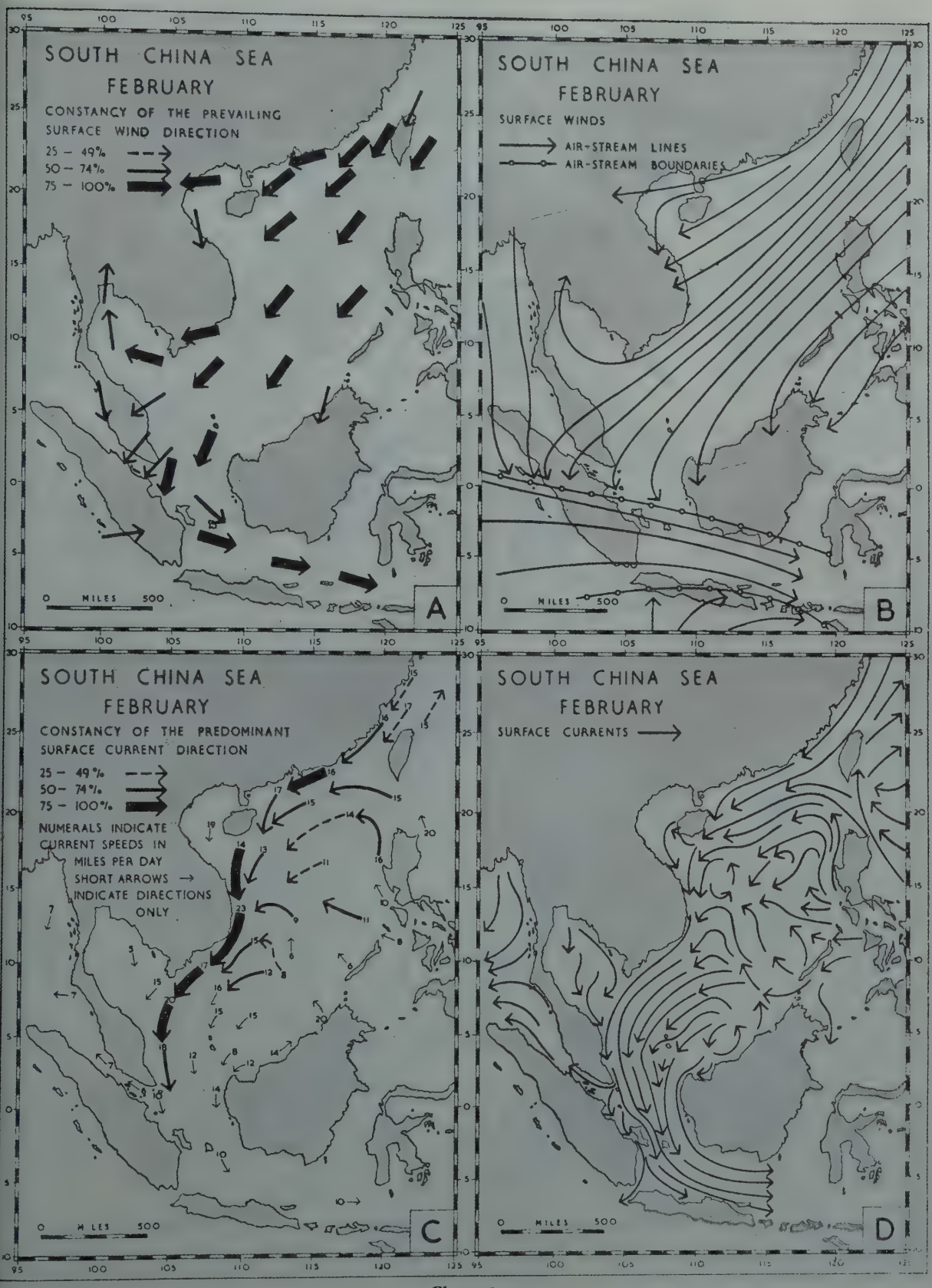
SOUTH CHINA SEA
FEBRUARY
CONSTANCY OF THE PREVAILING
SURFACE WIND DIRECTION
25 – 49%
50 – 74%
75 – 100%
0 MILES 500
A
SOUTH CHINA SEA
FEBRUARY
SURFACE WINDS
AIR-STREAM LINES
AIR-STREAM BOUNDARIES
0 MILES 500
B
SOUTH CHINA SEA
FEBRUARY
CONSTANCY OF THE PREDOMINANT
SURFACE CURRENT DIRECTION
25 – 49%
50 – 74%
75 – 100%
NUMERALS INDICATE
CURRENT SPEEDS IN
MILES PER DAY
SHORT ARROWS →
INDICATE DIRECTIONS
ONLY
0 MILES 500
C
SOUTH CHINA SEA
FEBRUARY
SURFACE CURRENTS
0 MILES 500
D

Chart 5

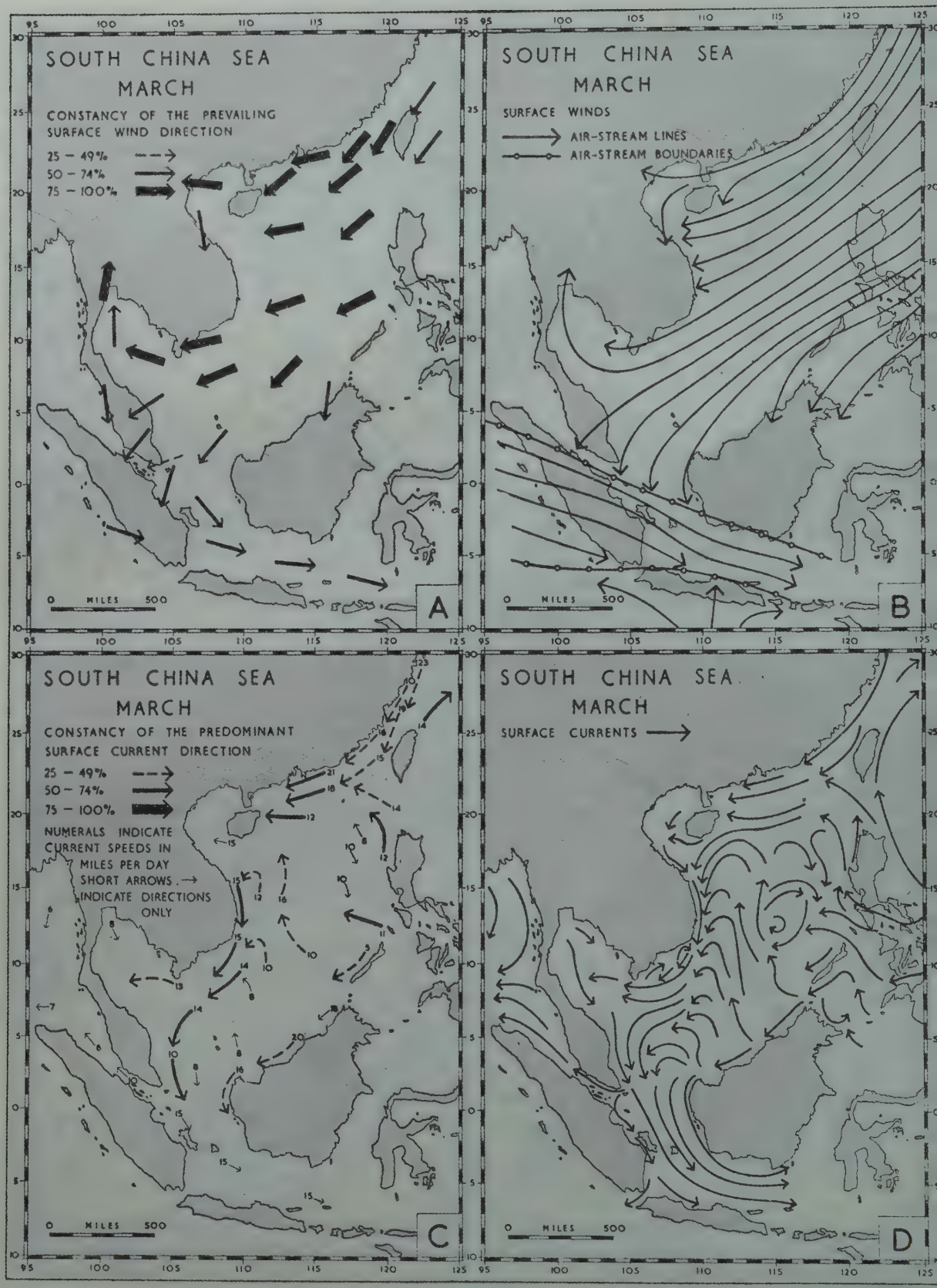
SOUTH CHINA SEA
MARCH
CONSTANCY OF THE PREVAILING SURFACE WIND DIRECTION
25 – 49%
50 – 74%
75 – 100%
0 MILES 500
A
SOUTH CHINA SEA
MARCH
SURFACE WINDS
AIR-STREAM LINES
AIR-STREAM BOUNDARIES
0 MILES 500
B
SOUTH CHINA SEA
MARCH
CONSTANCY OF THE PREDOMINANT SURFACE CURRENT DIRECTION
25 – 49%
50 – 74%
75 – 100%
NUMERALS INDICATE CURRENT SPEEDS IN MILES PER DAY
SHORT ARROWS → INDICATE DIRECTIONS ONLY
0 MILES 500
C
SOUTH CHINA SEA
MARCH
SURFACE CURRENTS
0 MILES 500
D

Chart 6

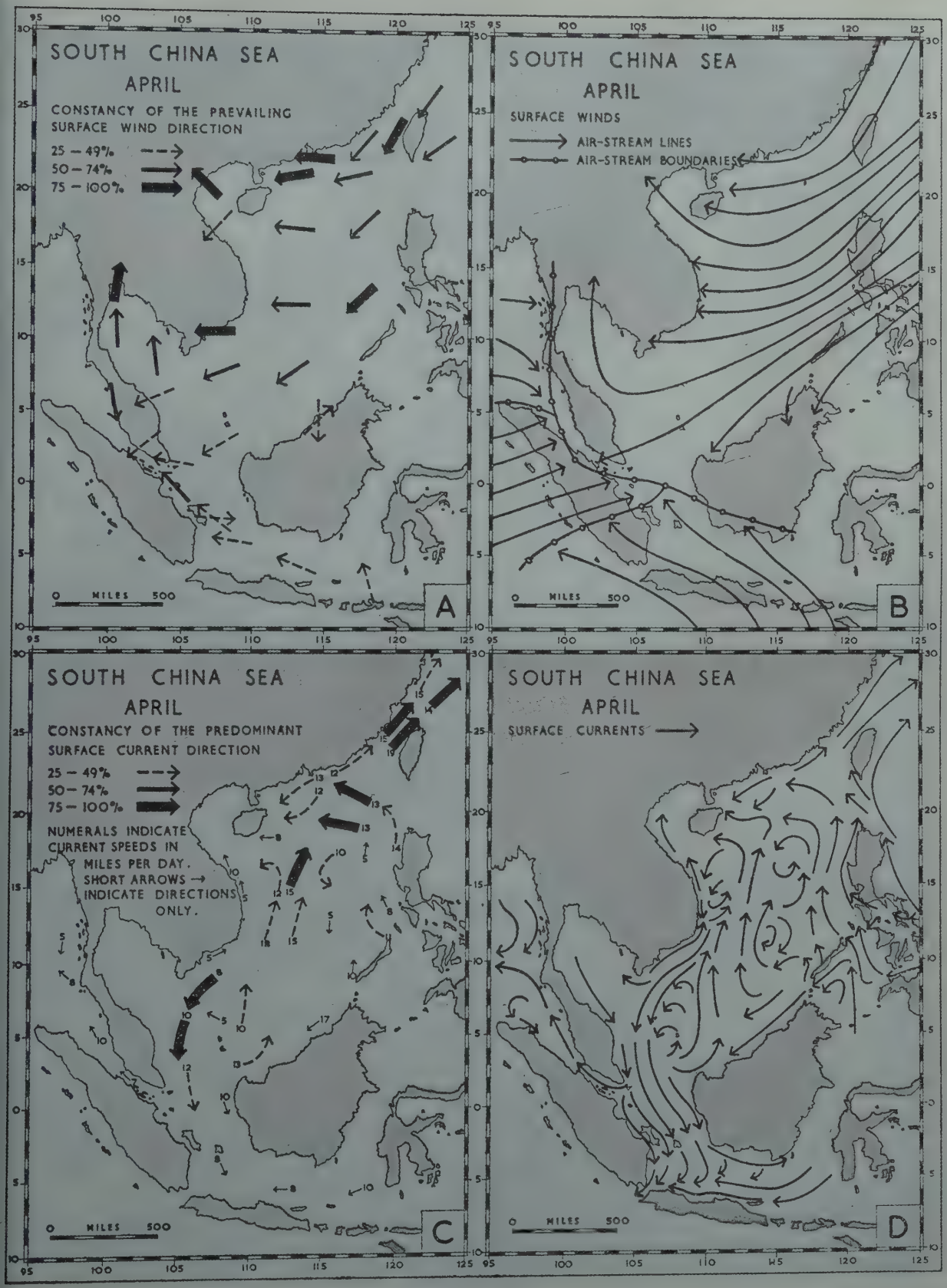
SOUTH CHINA SEA
APRIL
CONSTANCY OF THE PREVAILING SURFACE WIND DIRECTION
25 – 49%
50 – 74%
75 – 100%
0 MILES 500
A
SOUTH CHINA SEA
APRIL
SURFACE WINDS
AIR-STREAM LINES
AIR-STREAM BOUNDARIES
0 MILES 500
B
SOUTH CHINA SEA
APRIL
CONSTANCY OF THE PREDOMINANT SURFACE CURRENT DIRECTION
25 – 49%
50 – 74%
75 – 100%
NUMERALS INDICATE CURRENT SPEEDS IN MILES PER DAY. SHORT ARROWS → INDICATE DIRECTIONS ONLY.
0 MILES 500
C
SOUTH CHINA SEA
APRIL
SURFACE CURRENTS
0 MILES 500
D

Chart 7

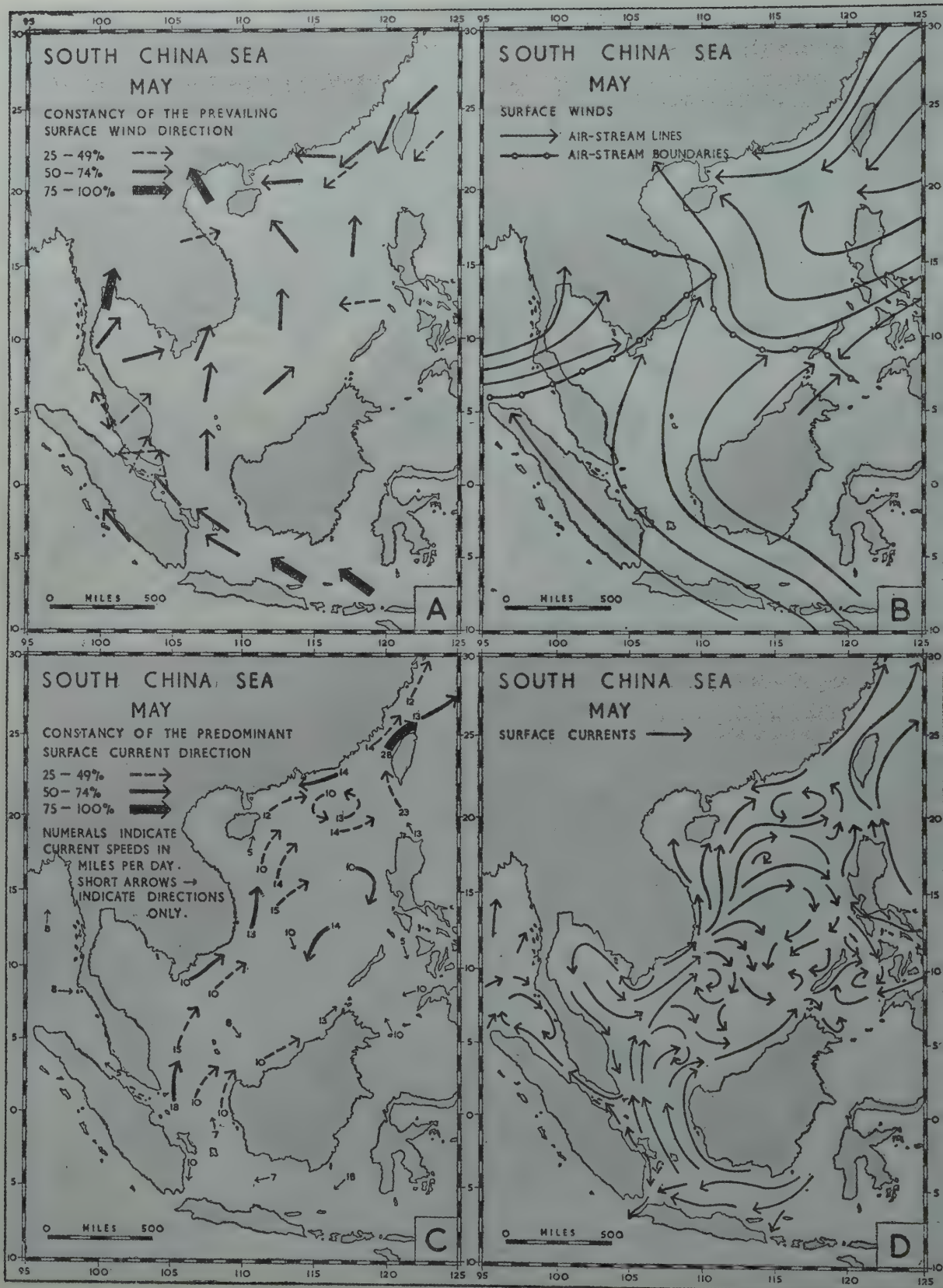
SOUTH CHINA SEA
MAY
CONSTANCY OF THE PREVAILING SURFACE WIND DIRECTION
25 – 49%
50 – 74%
75 – 100%
0 MILES 500
A
SOUTH CHINA SEA
MAY
SURFACE WINDS
AIR-STREAM LINES
AIR-STREAM BOUNDARIES
0 MILES 500
B
SOUTH CHINA SEA
MAY
CONSTANCY OF THE PREDOMINANT SURFACE CURRENT DIRECTION
25 – 49%
50 – 74%
75 – 100%
NUMERALS INDICATE CURRENT SPEEDS IN MILES PER DAY. SHORT ARROWS → INDICATE DIRECTIONS ONLY.
0 MILES 500
C
SOUTH CHINA SEA
MAY
SURFACE CURRENTS
0 MILES 500
D

Chart 8

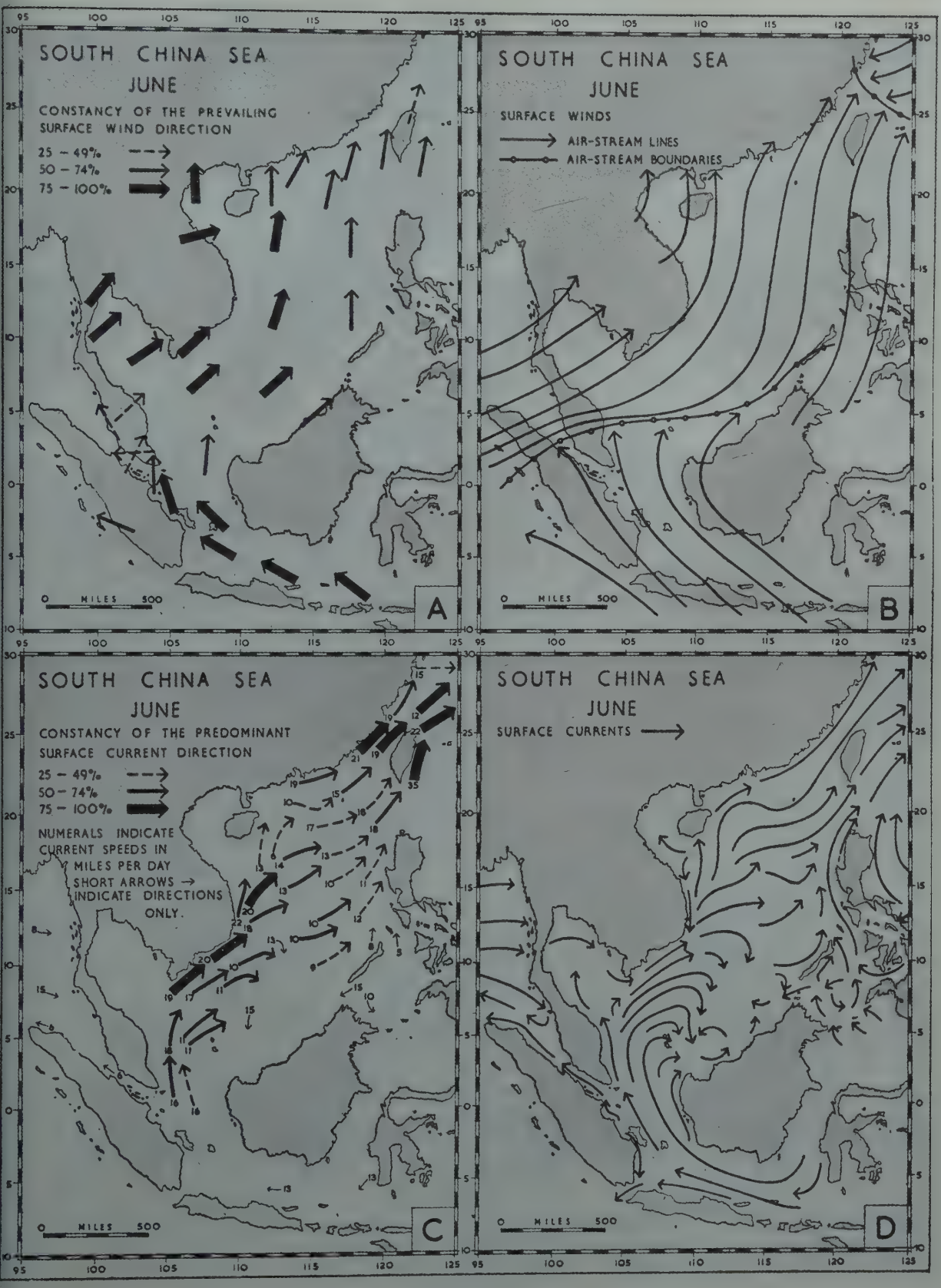
SOUTH CHINA SEA
JUNE
CONSTANCY OF THE PREVAILING SURFACE WIND DIRECTION
25 – 49%
50 – 74%
75 – 100%
0 MILES 500
A
SOUTH CHINA SEA
JUNE
SURFACE WINDS
AIR-STREAM LINES
AIR-STREAM BOUNDARIES
0 MILES 500
B
SOUTH CHINA SEA
JUNE
CONSTANCY OF THE PREDOMINANT SURFACE CURRENT DIRECTION
25 – 49%
50 – 74%
75 – 100%
NUMERALS INDICATE CURRENT SPEEDS IN MILES PER DAY
SHORT ARROWS → INDICATE DIRECTIONS ONLY.
0 MILES 500
C
SOUTH CHINA SEA
JUNE
SURFACE CURRENTS
0 MILES 500
D

Chart 9

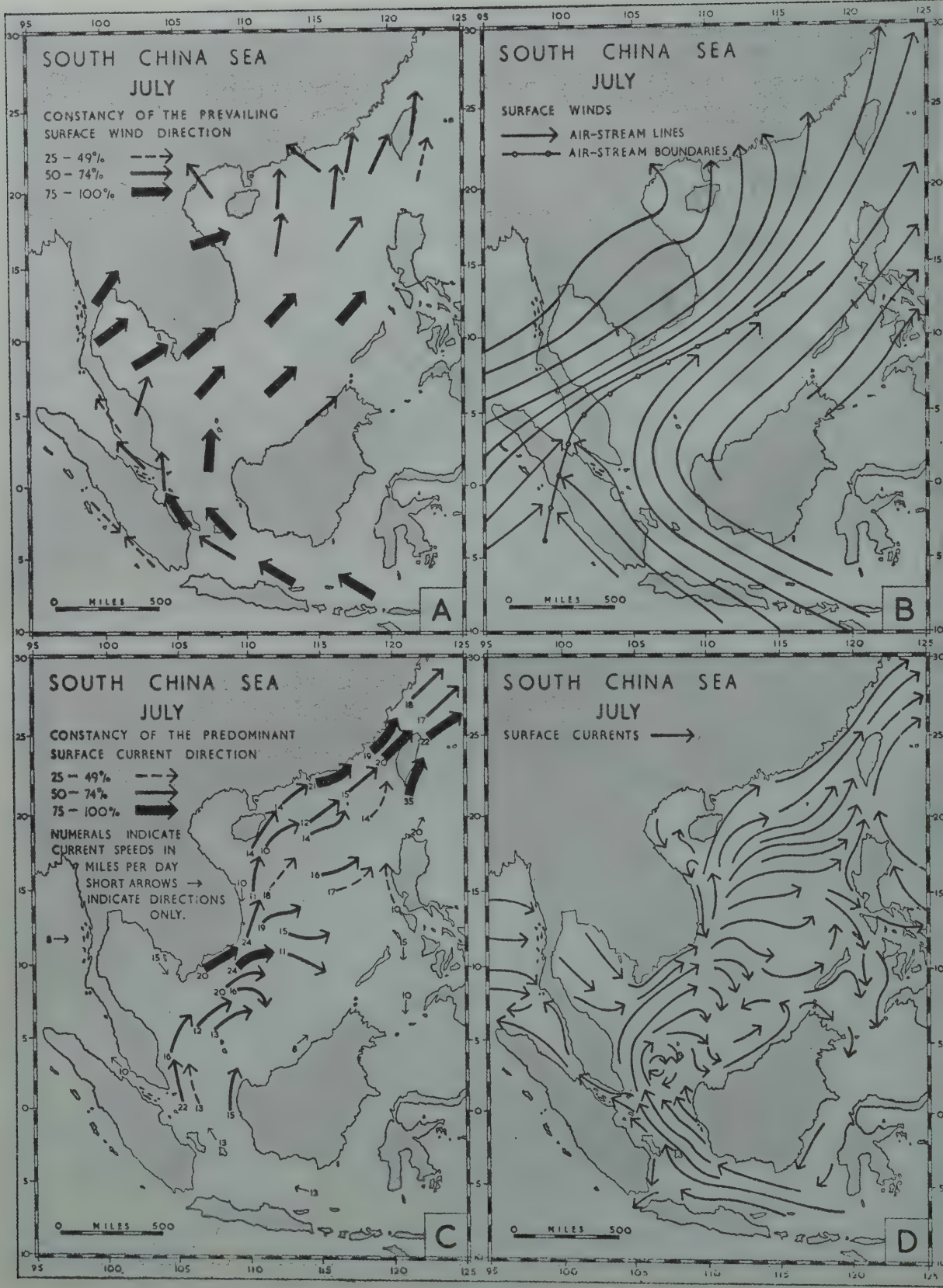
SOUTH CHINA SEA
JULY
CONSTANCY OF THE PREVAILING SURFACE WIND DIRECTION
25 – 49%
50 – 74%
75 – 100%
0 MILES 500
A
SOUTH CHINA SEA
JULY
SURFACE WINDS
AIR-STREAM LINES
AIR-STREAM BOUNDARIES
0 MILES 500
B
SOUTH CHINA SEA
JULY
CONSTANCY OF THE PREDOMINANT SURFACE CURRENT DIRECTION
25 – 49%
50 – 74%
75 – 100%
NUMERALS INDICATE CURRENT SPEEDS IN MILES PER DAY
SHORT ARROWS → INDICATE DIRECTIONS ONLY.
0 MILES 500
C
SOUTH CHINA SEA
JULY
SURFACE CURRENTS
0 MILES 500
D

Chart 10

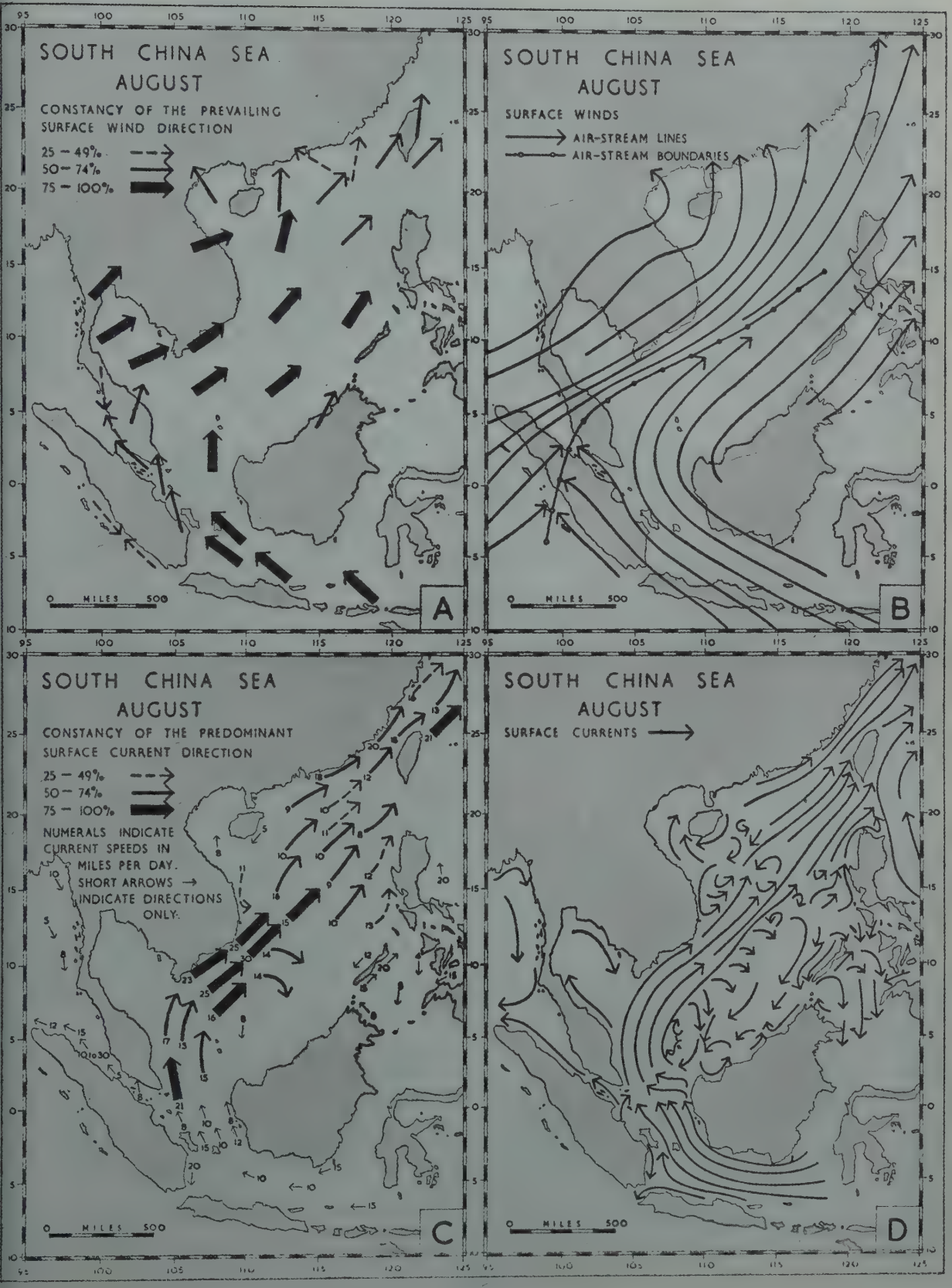
SOUTH CHINA SEA
AUGUST
CONSTANCY OF THE PREVAILING SURFACE WIND DIRECTION
25 – 49%
50 – 74%
75 – 100%
0 MILES 500
A
SOUTH CHINA SEA
AUGUST
SURFACE WINDS
AIR-STREAM LINES
AIR-STREAM BOUNDARIES
0 MILES 500
B
SOUTH CHINA SEA
AUGUST
CONSTANCY OF THE PREDOMINANT SURFACE CURRENT DIRECTION
25 – 49%
50 – 74%
75 – 100%
NUMERALS INDICATE CURRENT SPEEDS IN MILES PER DAY. SHORT ARROWS → INDICATE DIRECTIONS ONLY.
0 MILES 500
C
SOUTH CHINA SEA
AUGUST
SURFACE CURRENTS
0 MILES 500
D

Chart 11

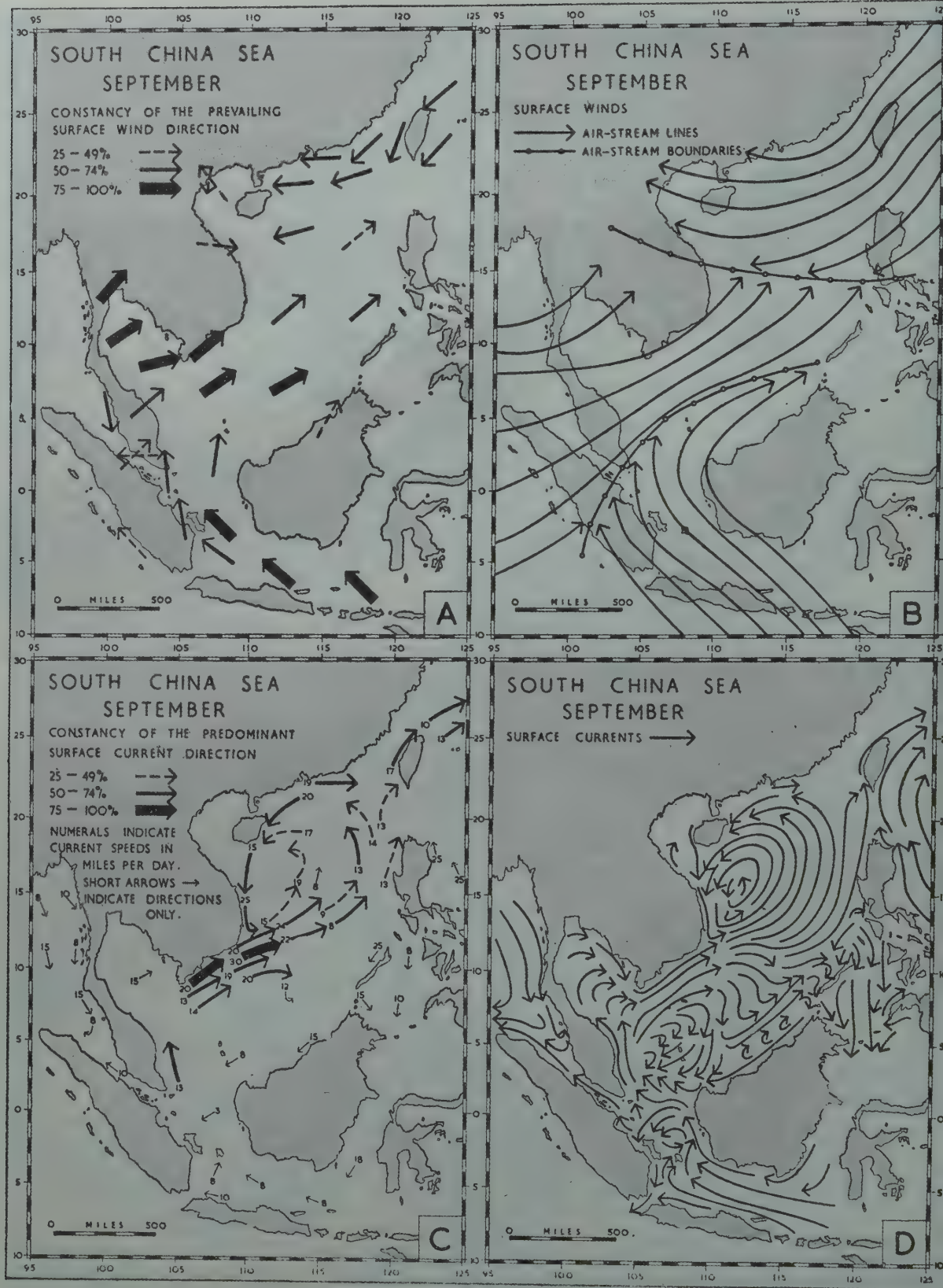
SOUTH CHINA SEA
SEPTEMBER
CONSTANCY OF THE PREVAILING SURFACE WIND DIRECTION
25 – 49%
50 – 74%
75 – 100%
0 MILES 500
A
SOUTH CHINA SEA
SEPTEMBER
SURFACE WINDS
AIR-STREAM LINES
AIR-STREAM BOUNDARIES
0 MILES 500
B
SOUTH CHINA SEA
SEPTEMBER
CONSTANCY OF THE PREDOMINANT SURFACE CURRENT DIRECTION
25 – 49%
50 – 74%
75 – 100%
NUMERALS INDICATE CURRENT SPEEDS IN MILES PER DAY.
SHORT ARROWS → INDICATE DIRECTIONS ONLY.
0 MILES 500
C
SOUTH CHINA SEA
SEPTEMBER
SURFACE CURRENTS
0 MILES 500
D

Chart 12

SEASONAL CHARACTER OF WINDS AND DRIFTS

Table 2 shows wind directions and strengths and drift speeds and directions month by month for every five degrees of latitude. Table 3 summarizes the

TABLE 2: SPEEDS AND DIRECTIONS OF WINDS AND DRIFTS

		0°-5° N	5°-10° N	10°-15° N	15°-20° N	20°-25° N	AVERAGE
OCT.	W	—	—	—	1-7 NE	4-7 NE	
	D	14 S	15 S	29 S	17 S	20 S	19 S
NOV.	W	—	1-7 NE	1-7 NE	4-12 NE	4-7 NE	
	D	14 S	21 S	31 S	20 S	19 S	21 S
DEC.	W	1-7 NE	4-7 NE	4-7 NE	4-12 NE	4-7 NE	
	D	15 S	19 S	30 S	19 S	19 S	20 S
JAN.	W	1-7 NE	4-7 NE	4-7 NE	4-7 NE	4-7 NE	
	D	12 S	16 S	25 S	13 S	14 S	16 S
FEB.	W	1-7 NE	1-7 NE	1-7 NE	1-7 NE	4-7 NE	
	D	14 S	17 S	19 S	13 S	13 S	15 S
MAR.	W	1-7 NE	1-7 NE	1-7 NE	1-7 NE	1-7 NE	
	D	9 S	14 S	15 S	—	20 S	14 S
APR.	W	—	1-7 NE	1-7 NE	1-7 NE	1-7 NE	
	D	11 S	9 S	—	—	N 15	10 S
MAY	W	S/SW 1-7	—	—	—	—	
	D	N 13	N 11	N 14	N 10	N 21	N 13
JUN.	W	S/SW 1-7	S/SW 1-7	S/SW 1-7	S/SW 1-7	S/SW 1-7	
	D	N 16	N 13	N 16	N 13	N 17	N 15
JUL.	W	S/SW 1-7	S/SW 4-7	S/SW 4-7	S/SW 1-7	S/SW 1-7	
	D	N 16	N 17	N 19	N 12	N 16	N 16
AUG.	W	S/SW 1-7	S/SW 1-7	S/SW 1-7	S/SW 1-7	—	
	D	N 16	N 19	N 19	N 12	N 14	N 16
SEP.	W	S/SW 1-7	S/SW 1-7	S/SW 1-7	—	1-7 NE	
	D	N 13	N 17	N 19	N 13. 15 S	N 14	N 15

Note. W = Wind. D = Drift. Numbers in the wind columns refer to the Beaufort Scale of Wind Force (see Appendix). Numbers in the drift columns are speeds in miles per day. Wind direction means direction from which the wind comes, drift direction means the direction towards which the water moves.

direction and approximate duration of the main winds and drifts of the year for every five degrees of latitude. Figure 3 is a diagrammatic representation of the information contained in Table 3.

TABLE 3: WIND AND DRIFT SEASONS

LATITUDE	SOUTHERLY OR SOUTH-WESTERLY WINDS	NORTH-SETTING DRIFT	NORTH-EASTERLY WINDS	SOUTH-SETTING DRIFT
20°-25° N	JUNE-JULY (2 MONTHS)	APRIL-SEPT. (6 MONTHS)	SEPT.-APRIL (8 MONTHS)	OCT.-MARCH (6 MONTHS)
15°-20° N	JUNE-AUG. (3 MONTHS)	MAY-SEPT. (5 MONTHS)	OCT.-APRIL (7 MONTHS)	SEPT.-FEB. (6 MONTHS)
10°-15° N	JUNE-SEPT. (4 MONTHS)	MAY-SEPT. (5 MONTHS)	NOV.-APRIL (6 MONTHS)	OCT.-MARCH (6 MONTHS)
5°-10° N	JUNE-SEPT. (4 MONTHS)	MAY-SEPT. (5 MONTHS)	NOV.-APRIL (6 MONTHS)	OCT.-APRIL (7 MONTHS)
0°-5° N	MAY-OCT. (6 MONTHS)	MAY-SEPT. (5 MONTHS)	DEC.-MARCH (4 MONTHS)	OCT.-APRIL (7 MONTHS)

Note. The wind columns apply to the entire longitudinal width of the South China Sea. The drift columns apply only to the western side of the Sea.

From a study of Tables 2 and 3 and Fig. 3, the two monsoons may be clearly distinguished at all latitudes. The times of beginning and ending of the seasons vary with distance from the equator. The south-west monsoon begins in May or June and ends in July, August, September or October according to latitude. The north-east monsoon begins in September, October, November or December and ends in March or April according to latitude. Between the two monsoon wind seasons are transitional periods lasting for about one month. The

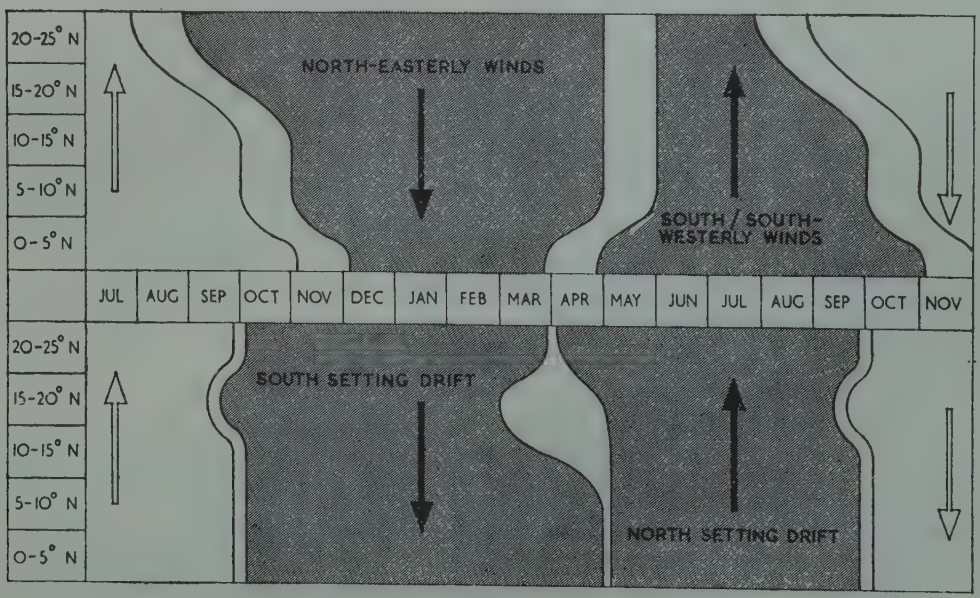

Fig. 3. Wind and drift seasons in the South China Sea.

monsoon seasons vary in length from two to eight months according to latitude. It seems unwise to define either the monsoon seasons or the transitional periods rigidly, for to do so might be misleading in view of the fact that the monsoons are apt to set in or come to an end earlier or later in some years than in others. Hence in this study the seasons are normally referred to in terms of the calendar months to which they approximate. Neither the timing of the seasons nor their length are invariable. The transition month is here taken as the one during which the constancy of the prevailing surface wind direction falls to a minimum. This usually means a fall to below 60 per cent, frequently it involves a fall to below 50 per cent. As a general rule it is found that the month so indicated is also the one during which a maximum number of calm days is recorded, as would be expected during the inter-monsoon period.

The surface drift-current directions on the western side of the Sea also show a marked seasonal rhythm. The close similarity between wind and current seasons is evident from Tables 2 and 3, and from Fig. 3. A north-setting drift current flows from April or May until September, and a south-setting drift from September or October until March or April. It is not possible to distinguish inter-monsoonal drift seasons, but it is apparent from the monthly analyses that during the inter-monsoon periods drift directions in the Sea are particularly variable and their speeds abnormally low. Over most of the Sea the establishment of the drift seasons tends to precede the onset of the corresponding wind seasons in the same latitude. The length of time by which the seasonal change in drift direction precedes the reversal of the winds varies with latitude. For example the commencement of southerly winds and the onset of a north-going drift are more or less simultaneous at the equator in May, but northwards from 5°N. the drift is observed several weeks before the arrival of southerly or south-westerly winds. Similarly, both the north-easterly winds and the south-setting drift arrive at the twentieth parallel early in October, but at the equator the south-going drift is observed in October whereas the north-easterlies do not reach there until late November or early December.

DURATION OF THE WIND AND DRIFT SEASONS

As may be seen from Table 3 and Fig. 3 the duration of the wind seasons varies considerably with latitude. The further the wind travels from its source the shorter its season becomes. At the equator winds associated with the south-west monsoon prevail for six months (May to October), whereas at lat. 25°N. they seldom persist for more than two months (June and July). Similarly, northerly winds prevail for eight months (September to April) at lat. 25°N. as compared with only four months (December to March) at the equator. The north-easterly wind season lasts longer than the southerly or south-westerly wind season, except to the south of latitude 5°N. where the wind season associated with the south-west monsoon is the longer.

The length of the drift seasons does not vary so much with latitude as do the wind seasons. The north-setting drift flows, on an average, for five months (between April and September), and the south-setting drift for six and a half months (between September and April). Thus over most of the South China Sea both the winds and the drift currents from the north persist longer than those coming from the south.

WIND AND CURRENT SPEEDS

Table 2 shows the approximate wind and current speeds for each month. The numbers in the wind columns indicate that at least sixty per cent of all wind observations are of the strength stated and that their direction is in the quadrant of the prevailing wind. The figures in the drift columns refer to the speed of the main north- and south-setting drifts, usually found on the western side of the Sea. It is not possible to identify such well marked drifts anywhere on the eastern side of the Sea. Drift speeds and directions on the east appear to be highly variable throughout most of the year.

It is apparent from Table 2 that winds of Force 4 to 7 and persisting for at least 60 per cent of the days of the month are characteristic over the open sea north of lat. 5°N during much of the north-east monsoon season. On the other hand, the percentage of days with winds stronger than Force 4 is much less during the south-west monsoon season. Only in July do the south-westerlies maintain a strength of Force 4 to 7 for at least sixty per cent of the days of the month, and then only between latitudes 5° and 15°N.

Climatological Tables for the Sea[1] show that winds of Force 8 to 12 are experienced over some part of the Sea in every month from October to February that is, during the north-east monsoon. Wind speeds greater than Force 8 are not experienced at any other time except July. The average force of the north-easterlies over most of the South China Sea is Beaufort Force 5; in the Formosa Strait it increases to Force 6 and south of the fifth parallel it decreases to Force 4. The south-westerlies and southerlies reach their greatest strength of Force 4 to 5 over the southern part of the Sea; north of latitude 15°N their strength decreases to Force 3.

WATER STOWAGE

So far discussion has been confined to the relationship between the winds and horizontal movements of surface waters. There are, however, seasonal changes in the mean level of the sea which, like the currents, appear to be closely related to the wind seasons. Chart 13 illustrates the way in which the mean level of the sea changes with the season at twenty-one stations in the South China Sea. The station graphs are drawn from tables published in Part II of the *Admiralty Tide Tables*.[7] A brief survey of the situation in each month will be given, followed by some general observations.

The mean level of the sea in October is almost everywhere above M.S.L. (the abbreviation M.S.L. is here used to refer to the mean sea level for the year, as distinct from the mean level in any one month). On the west side of the Sea and north of lat. 9°N the mean level is 7 in. above M.S.L. South of the ninth parallel it is slightly below M.S.L., but everywhere on the west the mean level of the sea is rising. On the east side of the Sea and north of Borneo the mean level is above M.S.L. but has a tendency to fall. The rise in level on the west and the fall on the east is related to the replacement, in September and October, of the south-westerly winds by north-easterlies, and the accompanying change in the pattern of the currents. The winds tend to depress the level of the sea on the east and to raise it on the west. Winds and currents combine to produce a piling up of water in the north-western part of the South China Sea between lats. 12° and 20°N. Currents from three directions contribute towards an exceptional stowage of water in that area. There is, first, a strong current setting south-west through Formosa Strait and thence along the south coast of China to the coast of Annam. A second source of water is provided by a branch of the

Chart 13. Water stowage.

Kuro Shiwo, which enters the Sea through Luzon Strait and drifts westwards in the direction of Hainan. The third supply comes from a drift which sets to the north along the west coast of the Philippines and is deflected westwards by the branch of the Kuro Shiwo and the north-easterly winds, opposite Luzon Strait. Thus all three drifts converge in the north-west, resulting in a considerable accumulation of water in that part of the Sea. It appears that this unusually high mean level of the sea in the north-west provides a hydrostatic head, from which the newly established south-going drift, in the southern part of the Sea, derives sufficient energy to flow at a remarkably high speed in opposition to the prevailing south-westerlies (see Chart 1).

Early in November the stowage of water in the north-west reaches a maximum. The mean level of the sea there is then 10 in. above M.S.L., whereas

the level in the south-west is only 3 in. above M.S.L., and on the eastern side of the Sea it is less than 2 in. above M.S.L. This further development of the hydrostatic head in the north-west would explain why, in November, the drift current off the coast of Annam sets to the south at an average speed of 40 miles per day. This is the highest average speed for any part of the South China Sea in any month of the year. It is true that by this time the north-east winds have invaded most of the Sea, but off the coast of Annam they are still weak and variable, and could not, of their own accord, generate such a high speed in the sea below. In December and January the north-easterlies have greater strength and constancy but the current in the sea below them is considerably slower than in November.

Throughout December the further advance and strengthening of the north-easterlies is reflected in the slow but steady fall of the mean level of the sea on the east, and a rise along the coast of Malaya and Sarawak. The rapid rise noticed in the north-west in October and November is now arrested or even reversed, due to the general surge of water from the north to the south with the full establishment of the north-east monsoon over the entire Sea. The speed of the drift off the coast of Annam averages 36 miles per day as compared with 40 miles per day in November. The average elevation of the mean level of the sea above M.S.L on the west in December is slightly more than 7 in., which is the largest average deviation from M.S.L. for either side of the Sea at any time of the year. On the east, north of lat. 12°N, the mean level of the sea falls to 1 in. below M.S.L. but remains above M.S.L. south of this latitude, due to the direction of the north-easterlies being parallel with the coast or slightly off-shore.

Conditions in January are similar to those for December. A maximum piling up of water occurs along the east coast of Malaya, whilst the level falls rapidly along the east coast of Indo-China, and the drift off Annam is further reduced in speed to 30 miles per day.

In February the mean level of the sea tends to fall at all stations. North of lat. 12°N the east side experiences its maximum depression of $2\frac{1}{2}$ in. below M.S.L. early in the month, that is soon after the north-east monsoon has reached its maximum strength.

The only stations recording an elevation above M.S.L. in March are found on the west side of the Sea, south of lat. 13°N.

By the beginning of April the mean level is at, or below, M.S.L. almost everwhere in the South China Sea. During this month the east side of the Sea, south of lat. 12°N falls to its maximum depression of 2 in. below M.S.L.

In May almost all stations in the Sea record a mean level lower than that of M.S.L. The only exception to this general situation occurs along a short stretch of the west coast of Borneo between the equator and lat. 1°N. The depression on the east is of the order of 1 in., on the west it is $3\frac{1}{2}$ in. below M.S.L.

During June and July the mean level on the west, north of lat. 12°N, falls to its lowest level of 5 in. below M.S.L. South of lat. 12°N a maximum depression of more than 6 in. occurs at the end of July. The lowest mean level on the west side of the Sea coincides approximately with the height of the south-west monsoon.

Throughout July and August the mean level continues to rise on the east, and north of lat. 12°N a maximum elevation of $2\frac{1}{2}$ in. is recorded towards the end of August, when the south-west monsoon is about exhausted over the northern

part of the Sea. South of lat. 12°N a maximum elevation of 2 in. occurs in November during the transition between monsoons.

By the end of September the mean level of the Sea on the west is again above M.S.L. at most places. Although the north-east monsoon winds invade the northern part of the Sea in September, the mean sea level there remains well above M.S.L. on both sides of the Sea until a rapid fall sets in on the east at the end of October.

From the foregoing analysis it is evident that the rise and fall in the mean level of the Sea follows the general rhythm of the monsoons. It would appear that whilst the wind stress is to a great extent directly responsible for the drift currents of the Sea, it also exerts a less direct influence by producing changes in the mean level of the sea surface. The extent of this influence varies from place to place, and from time to time. Its effect is considerably greater on the west side of the Sea than on the east, and it would appear to be of greatest importance in the north-west during the months of October and November. Smaller hydrostatic heads may develop elsewhere in the Sea, causing the speeding up of some currents and the retarding of others. The seasonal rise and fall of the mean level of the sea must also effect the exchange of water between the South China Sea and its neighbours.

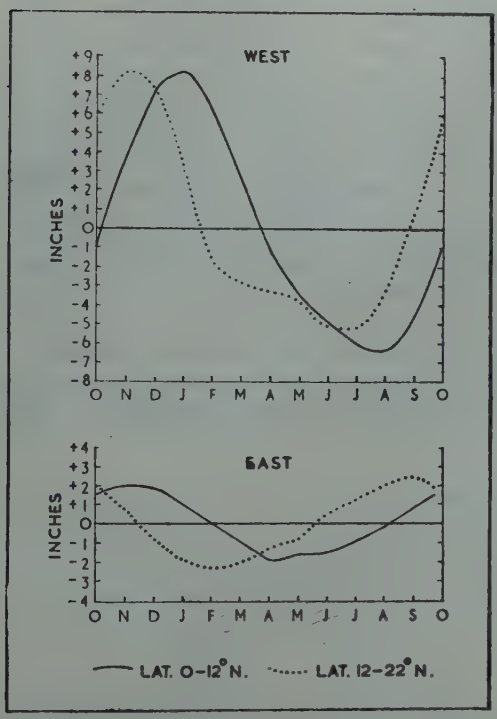

Fig. 4. Rise and fall of sea level on the east and west sides of the South China Sea.

Fig. 4 demonstrates the close relationship between the rise and fall of the mean level of the Sea on the west, and the monsoon wind seasons. North of lat. 12°N the maximum elevation above M.S.L. occurs at the end of October and in November, that is during the first half of the north-east monsoon. The minimum level is recorded in June and July at the height of the south-west monsoon. South of lat. 12°N the maximum elevation occurs towards the end of December and in January at the height of the north-east monsoon. The lowest mean level is reached in July and August at the peak of the south-west monsoon. On the eastern side of the Sea, north of lat. 12°N, a maximum elevation is experienced in August and September at the end of the south-west monsoon, and a maximum depression in February during the north-east monsoon. Between lats. 12°N and 4°N the maximum departures from M.S.L. tend to coincide with the inter-monsoon periods rather than with the monsoon seasons. Thus the mean level of the sea there reaches its highest in November and December, and its lowest in April. South of lat. 4°N the behaviour of the mean level of the sea is similar to that for the east coast of Malaya.

The average range of the rise and fall in the mean level of the sea is greater on the west than on the east. The average figure for the west is 13 in.

as compared with 4 in. on the east. One of the largest recorded ranges for a coastal station is that for Dendang (lat. 0° 51′ N, long. 104° 37′ E) where the mean level in January is 23 in. above that for August. The effects of a large annual range in the mean level of the sea are enhanced by the very gentle slope of the sea floor along the east coast of the Malay Peninsula, and elsewhere along the coastlines of the Sunda Shelf.

From the middle of October until late in November the mean level of the sea is almost everywhere above M.S.L. The elevation is five times as great on the west as on the east side of the South China Sea. Between the middle of March and the end of May the mean level is almost everywhere below M.S.L. The depression on the west is then five times as great as that on the east. It would thus appear that the South China Sea contains a maximum volume of water during the early part of the north-east monsoon and a minimum volume during the transition period from the north-east to the south-west monsoon.

CONCLUSION

The influence of wind stress upon the waters of the South China Sea is thus considerable. As yet, knowledge of conditions in both the sea and the atmosphere of the South China Sea area is scanty, and much more information is required before a thorough appreciation of the movements of the surface waters can be made. Large areas of the Sea are still little explored, details of current movements are inadequate and observations of atmospheric conditions are also wanting at some places. The influence of water stowage is likely to be much greater than this study suggests. One difficulty of demonstrating this is that the heights of sea level for South China Sea stations are not related to a common datum level, making it impossible to assess fully the piling up of water in different parts of the Sea.

Whilst wind may be a major factor influencing surface water movements, other factors modify the pattern of currents produced by the wind. Amongst these are density of sea water, submarine topography, coastal configuration and tides.

APPENDIX

THE BEAUFORT SCALE OF WIND FORCE

BEAUFORT NUMBER	DESCRIPTIVE TITLE	RANGES OF SPEED (M.P.H.)
0	CALM	LESS THAN 1
1	LIGHT AIR	1 - 3
2	LIGHT BREEZE	4 - 7
3	GENTLE BREEZE	8 - 12
4	MODERATE BREEZE	13 - 18
5	FRESH BREEZE	19 - 24
6	STRONG BREEZE	25 - 31
7	MODERATE GALE	32 - 38
8	FRESH GALE	39 - 46
9	STRONG GALE	47 - 54
10	WHOLE GALE	55 - 63
11	STORM	64 - 75
12	HURRICANE	ABOVE 75

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AVATIME

A HIGHLAND ENVIRONMENT IN TOGOLAND[1]

By H. P. WHITE

In West Africa relief is on the whole subdued and dissection mature. Even in the restricted areas of highland (over 3,000 ft.), such as the Futa Jalon, the Jos Plateau of Nigeria and the Bamenda Highlands of the Cameroons, steep slopes and rugged topography are generally confined to the plateau edges. While altitude may occasionally be a factor in shaping the human response, control exerted by steep slopes and youthful stages of dissection is even more rare. One such example does, however, exist in the small mountain state of Avatime in the highlands of that part of Togoland under British trusteeship and at present administered as an integral part of the Gold Coast.

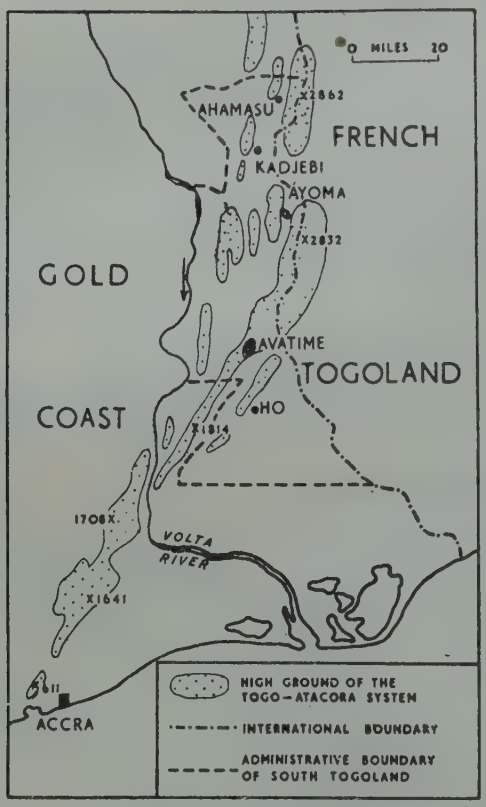

Fig. 1. Key map.
Spot heights (x) are in feet.

A good map of West Africa[2] will show a continuous belt of highland, known as the Togo-Atacora Range, extending from the coast immediately west of Accra in a north by north-east direction almost as far as the Niger below Niamey, a distance of all but 500 miles. West of the Volta, where it is known as the Akwapim Range, it is low, never much exceeding 1,200 ft., and narrow. Beyond the river, however, it soon becomes higher and broader. In southern Togoland the highlands are in the form of a number of parallel ridges and highly dissected plateaux, which are separated by level, low-lying plains. The general trend is from south-south-west to north-north-east as far as the frontier with French Togoland. Here the trend swings, for the next seventy miles, to south-north, one of the ranges now forming the frontier.

Between the Volta and the frontier the main range is developed on the crystalline rocks, mainly quartzites and phyllites, of the Togo series, which, together with the slightly younger Buem series of shales and sandstones to the

1. The author wishes to acknowledge the valuable help derived from an unpublished dissertation for the B.Sc. degree of the University of London by J. G. A. Renner entitled *The Geology of Central Avatime*, and also from undergraduate members of the Geography Department of the University College of the Gold Coast, whose facts, collected as part of an exercise in field-work, form much of the basis of this study.
2. e.g., G. Grandidier, *Atlas des Colonies Francaises* (Paris, 1934), Plate XV.

north, overlies the gneisses of the Dahomeyan series.[1] Peneplanation, aided by some lithological differences, has led to the formation of the level, low-lying plains from which the residual ranges and plateaux rise very steeply to heights which are sometimes not far short of 3,000 ft. The main or Togo range, some six miles across in the Avatime area, rises steeply to summits about 2,250 ft. above sea level. To the south-east lies a narrow lowland, averaging 6-800 ft. above sea level and underlain by Dahomeyan gneisses, which separates the main range from the hills behind Ho. To the north-west of the main range is a much broader lowland, only 4-500 ft. high, beyond which rise the Kpandu Heights and the Togo Plateau, both developed on rocks of the Buem series.

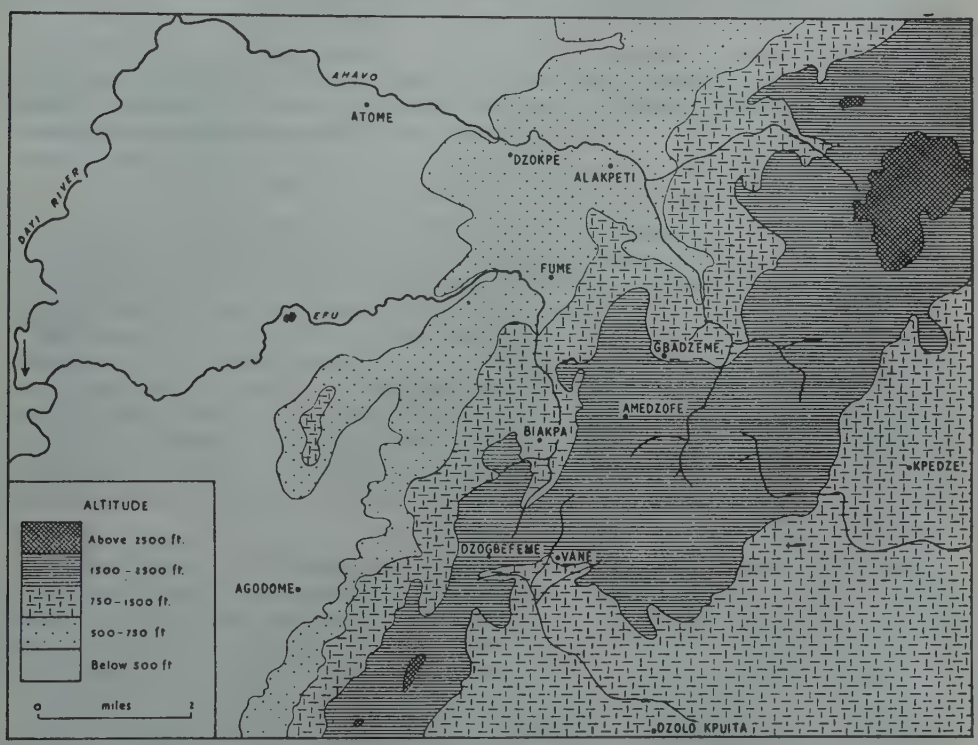

Fig. 2. Physical features of the Avatime area.

The main range is, in the Avatime area, composed of alternate strata of quartzite and phyllite, considerably folded, but with a general dip to the south-east. The geology is further complicated by faulting, mainly north-south and east-west, though the south-eastern scarp is probably fault-guided as well. The range is, at present, being subjected to vigorous internal dissection by a network of youthful streams.

This has resulted in the main range, at this point, being divided longitudinally into three by the action of the Efu and Ahavo streams, though the floors of these internal valleys are at a much greater height than are the flanking lowlands. Each ridge presents a steeper face to the north-west than to the south-east, the result of the regional dip. Transverse faulting and stream action have

1. The new nomenclature for these series has been used. See *Report of the Director, Gold Coast Geological Survey*, 1952-3 (Accra, 1954), p. 13.

also formed a number of high-level cols in the ridges, thus reducing these to a series of eminences with rounded summits and very steep sides. The most striking effect of faulting and associated erosion can, however, be seen between Vane and Fume villages, where the whole range can be crossed by a col at little more than 1,500 ft.

Slopes developed on the quartzites are precipitous, bare of soil and with accumulations of scree at their feet. On the other hand, slopes developed on the phyllites are not so steep and are covered in places with sufficient soil to support a dense forest growth, for the phyllites undergo decomposition into clay to a considerable depth. This clay has a more gentle angle of rest and thus allows soil formation.

There is some evidence of rejuvenation for there are nick-points on all the streams, including a spectacular waterfall on the upper Ahavo. The streams have also carved deep and narrow gorges into the floors of more open valleys. Where these upper levels are not continuous, in contrast to those at Biakpa, the remnants can be seen as flattenings on the slopes of the spurs. Everywhere they have a great significance in the siting of settlements and cultivated land.

The climate is equatorial, with constant high temperatures and two rainy seasons. The altitude is insufficient to have any significant effect on temperatures, and the fireplace in the living-room of the rest-house at Amedzofe, an almost unique feature in the Gold Coast, is more to repel damp than cold. The practical effect on vegetation is negligible. Rainfall is high; the twenty-year mean of Amedzofe being 73·81 in., and during the rainy seasons humidity is constantly high, the range being wrapped in mist for long periods. Much of the rain comes in heavy storms, accompanied by thunder and lightning. At the height of the main dry season, from December to February, conditions are in complete contrast due to the *harmattan* conditions brought by the north-easterly air stream. Humidity is low and conditions stable, but visibility is still bad, as a result of the dust-laden atmosphere.

Climate such as this results in dense forest growth on the highlands and also along the rivers of the lowlands. Rainfall is adequate, but the check to growth brought by the long dry season leads to a semi-deciduous type of forest. The dominant species are *Antiaris africana* and *Triplochiton scleroxylon*, trees of the dryer types of tropical forest.[1] There is, however, little forest left, and that secondary. It is usually to be found on the steeper slopes and in the gorges, where there is sufficient soil for tree growth, but where cultivation is impossible.

A striking feature is that, emerging above forest and farmland, the rounded summits are devoid of any vegetation but grass. This is most likely to be the result of the poverty of the skeletal soils developed on the quartzites. Many of the lower slopes now have a savanna vegetation, but this is doubtless the result of past clearances and subsequent over-cultivation.

Whatever their natural conditions in the past, apart from galleries along the water courses and immediately below the highlands, the plains are now covered with orchard bush, a close tree growth, stunted by fire and of an almost uniform height, with a continuous grass cover below. A brown landscape in the dry season, but a green one after rain.

This then is the environment shaping the way of life of the Avatime people, who inhabit a small area of some twenty square miles of the Togo Range and

1. C. J. Taylor, "The Vegetation Zones of the Gold Coast," *Forestry Department Bulletin No. 4* (Accra. 1952).

of the Dayi lowland to the north-west. It is tempting to see them as a remnant driven into the hills by the coming of the Ewe, now the dominent people of southern Togoland. Indeed some early writers take this view.[1]

Oral tradition is, however, quite clear that the Avatime are an Ahanta people from the south-western Gold Coast who arrived at their present home via the coast at a comparatively late date, after most of the land was already occupied by Ewe. They conquered and settled this particular terrain, which incidentally offered good protection in the intertribal warfare which lasted until pacification by the Germans in the latter part of the nineteenth century. The indigenous people, the Bayas, were absorbed rather than exterminated and their descendants form one of the clans in several of the villages. The coconut, which is common in the lower-lying villages, is said to have been brought by the Avatime from their original home, where it abounds to-day. The Avatime preserve their own language, though all speak Ewe, which is also the vernacular taught in the schools. They also have their distinct tribal deity.

At first pressure on land would have been slight, for the flattish shoulders on the valley spurs, the remnants of former river levels, and the less steep slopes developed on the phyllites were available for cultivation. Land ownership is vested in the clans, of which there are several in each village. The clan land is divided before each season among the individual families making up the clan. At Gbadzeme, for instance, it is customary for each clan to clear a continuous area of land, though the individual owners will cultivate, plant and harvest their crops severally. Land reverts to the clan after harvest, except in the case of permanent tree-crops such as cocoa. The 'bush-fallow' rotation, practised here as almost everywhere in West Africa, is thus achieved in large blocks of cultivation and fallow. This is in contrast with much of the Gold Coast, where it is customary for individual holders to retain their rights over fallow land, so that the cultivated land is in small, irregularly shaped and widely scattered parcels.

The chief food crop is hill rice, apparently the original staple as fertility and harvest ceremonies centre on this crop. Other grains, maize and sorghum mainly, are grown, but to a lesser extent. Yams and cassava are the main root crops, while round the villages are numerous fruit trees, bananas, mangoes, oranges and coconut palms. Cotton is also grown as part of the subsistence economy. All field crops are grown in mixed stands.

The principal cash crops are coffee and cocoa. The former was introduced and encouraged by the Germans, but since 1914 it has had a very chequered existence, though there has been some stimulus from the high prices which have ruled almost continuously since 1945. It is grown near the villages, on the hill slopes, and under shade where possible. Cocoa is a more recent introduction and has come to be of greater importance. Cocoa trees are found almost everywhere that there is still sufficient tree cover to offer shade, sometimes on very steep slopes.

These lands, within the main range, represent the primary stage of settlement. They are obviously very restricted, for there is little land suited to cultivation and much of this small area must be under fallow at any one time. No more than a few hundred acres can, therefore, be under crops.

With the advent of peaceful conditions pressure of population soon began to be apparent. Intensification of land use is not possible with the 'bush-fallow'

1. H. Baumann and D. Westermann, *Les Peuples et les Civilisations de l'Afrique* (French trans. Paris, 1948), p. 408; also T. Robertson, *Report on the Geology of Western Togoland* (London. 1921), p. 9.

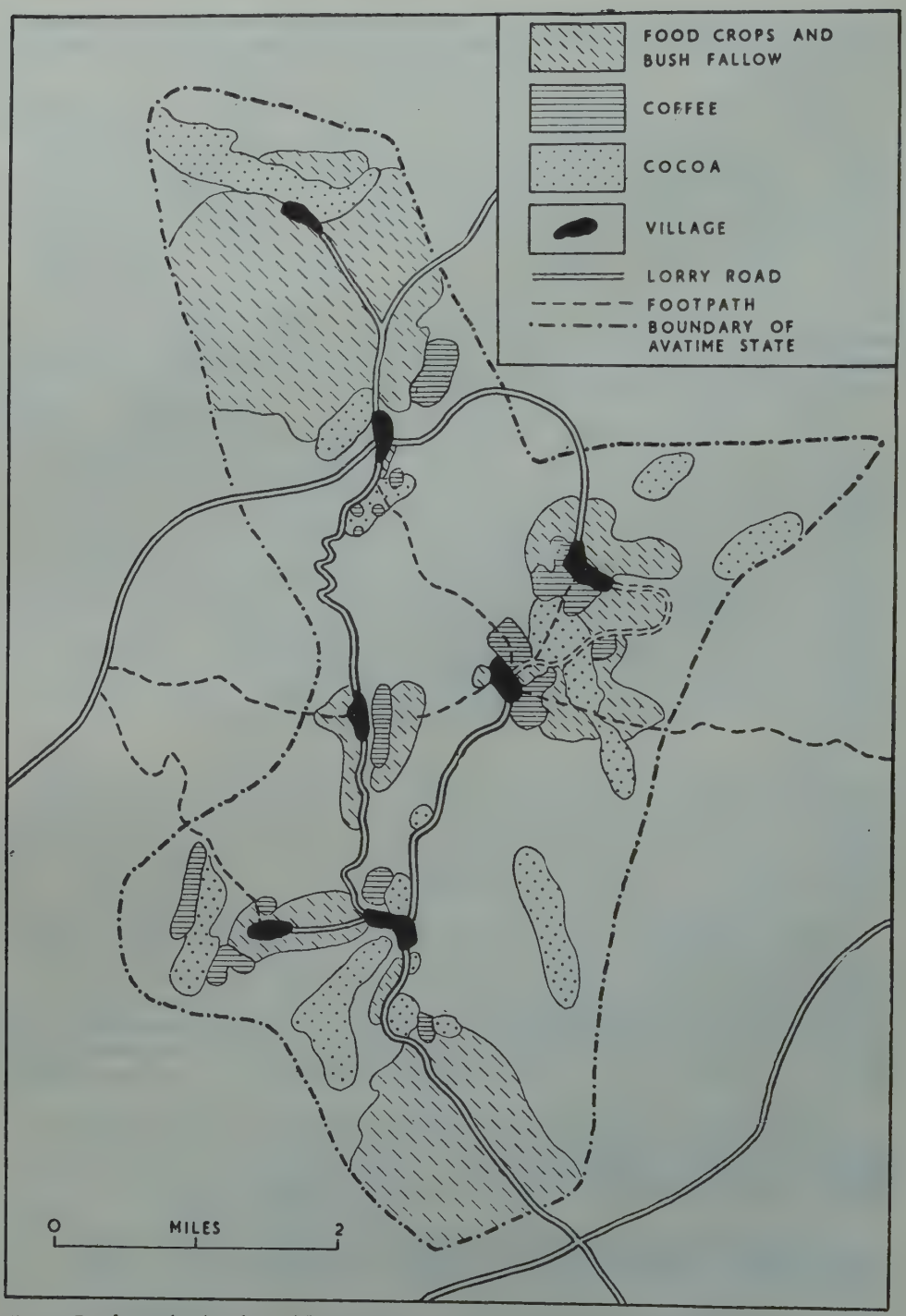

Fig. 3. Land use in Avatime. The boundary of Avatime State has not been surveyed and is therefore only approximate. The unshaded areas within Avatime State are 'waste', including secondary forest, grassland, savanna of various types and outcrops of bare rock.

system of agriculture unless the fallow periods are shortened. This can only be done to a certain extent without unduly lowering fertility. The alternative is to bring more land under cultivation and fallow. Within the mountains this is not possible without terracing. This is by no means unknown in West Africa; there are terraces in the greenstone hills of the extreme north-east of the Gold Coast and extensive terracing in the highlands of the Cameroons,[1] but the Avatime have not adopted this method.

Instead the cultivation of the lowlands at the foot of the range began. Low-lying land below Vane was cultivated by that village. An embayment in the fault-guided scarp has been formed at the southern and of the transvers fault already referred to. Numerous springs break out around the edges and the area is thus very swampy at certain seasons. High-yielding swamp rice is grown, though not by the methods usually associated with that crop. Irrigation is not practised, nor is transplanting.

To the north-west of the range, the Dayi plains were being settled around the turn of the century. To ensure a share to Avatime, families were selected from each of the six earlier villages to found the new village of Dzokpe. Here, out on the plain, conditions are much dryer. Cocoa can only be grown under the shelter of the gallery forest along the Ahavo below where it emerges from the Togo Range. On the savanna lands on either side of the river maize, cassava, yams and hill rice are grown.

Even with this extension of tribal land it is evident that land available for cultivation is quite inadequate to support the present population. The Avatime live in seven small, nucleated villages, of which Vane is the headquarters of the paramount chief. The hill villages are sited on the relatively level ground on the shoulders of the valley spurs. Gbadjeme is in a spectacular amphitheatre below the Ahavo falls, and is surrounded by its cultivated lands on the lower slopes of the amphitheatre. Fume lies at the foot of the Togo Range and Dzokpe out on the plains, the only one with an unrestricted site.

In these seven villages the population as recorded in the 1948 census was 5,128.[2] As the boundaries of the state have not been surveyed, it is not possible to measure its area accurately, but it is about 22⅓ sq. miles. This gives us an overall density of some 230 persons per sq. mile, compared with the Gold Coast average of 45. But much of the area, perhaps a third, has slopes of 1 in 5 or steeper, and is thus completely useless for cultivation, at least without terracing. The only suitable areas, apart from the lowlands of Vane, Fume and Dzokpe, are the flattish summits east of Amedzofe, the more open upper Efu valley, and the amphitheatre of Gbadzeme. Even so, many very steep slopes are brought under cultivation, those along the path from Gbadzeme to Amedzofe being at least 1 in 7.

Thus cultivable land cannot much exceed 15 sq. miles, and much of that must be in fallow, one third at least, even if fallow periods are reduced to a very dangerous level from the point of view of maintaining fertility. So a conservative estimate of the density of population per sq. mile of land in crops is over 500. It must be noted that this figure is provisional and is liable to revision in the light of more precise details non-existent at present. Under West African systems of cultivation and with even the simplest of economic needs to fulfil, this is an impossibly high figure if the population depends solely on its own resources of

1. S. White, "Agricultural economy of the hill pagans of Dikwa Emirate (Cameroons)," *Empire Journal of Experimental Agriculture*, vol. 9, no. 35 (London, 1941).

2. *Gold Coast Government: Census of Population*, 1948 (London 1950).

Table 1: POPULATION OF AVATIME (From the Gold Coast Census of 8th February, 1948)

	Total Population	Females per 1,000 Males		Approx. Density per Sq. Mile	Literates per 1,000[3]	Area in Sq. Miles
		All Ages	Over 16			
VANE	929	1,142	1,368	180	69	5·2
AMEDZOFE[1]	1,685	776	737	450	334	3·8
BIAKPA	467	1,022	952	330	45	1·4
DZOGBEFEME	310	1,053	1,085	140	35	2·2
DZOKPE	470	1,071	1,162	160	34	3·0
FUME	260	955	1,053	60	8	4·3
GBADZEME[2]	1,007	1,043	1,150	420	142	2·4
AVATIME	5,128	966	988	230	158	22·3

agricultural production. Unless there is an alternative form of income, cash or kind, sheer starvation will be the common lot of Avatime.

Two attempts have been made to solve the problem, the development of a textile industry *in situ* and emigration. The Avatime have long grown and processed cotton. The product is a heavy and coarse fabric usually made up into working tunics or sweat towels. The loom is crudely made with a shuttle throw of only six inches. The long, narrow strips of cloth have therefore to be sewn together after weaving. Slow as is the weaving, as in most hand-operated textile industries it outstrips the output of the spinners. It takes a day and a half to spin enough yarn to keep a loom busy for two hours. Weaving is a man's task, spinning a woman's.

The product of this industry is sold only locally, but during and after the last war it was decided to employ the weaving skill of the Avatime in a commercial enterprise. The idea was to produce cloth for general sale on broad looms with a 48-in. throw. Hand looms were set up in weaving sheds at Vane and Gbadzeme. Though the cloth was woven in traditional formal designs, imported ready-dyed yarn was used as the new looms would obviously use far more yarn than could be produced locally. Unfortunately the venture did not meet with the success it deserved. The product, of medium quality, could not compete with the cheap, imported printed cloth, while the standard was not equal to the very elaborate '*Kenti*' cloths worn on formal occasions and for which high prices are paid. The Avatime looms are now used only very spasmodically.

The effect of population pressure was clearly shown when master weavers were not only content, but anxious, to work for 3s 9d. per day at a time when craftsmen were paid anything from 5s. 5d. to 9s. 4d. in other parts of the country. Furthermore they clung tenaciously to this new commercial outlet even after several failures. They were, of course, not completely dependent on their earnings for all had small food farms.[4]

The second outlet, emigration, has been more successful. In the main it has been an emigration of farmers to the cocoa-growing area of Buem to the

1. Includes Presbyterian Teacher Training College (approximately 140 staff and students).
2. Includes Government Girls' Middle School (boarding).
3. To indicate effect on population figures of educational establishments catering for areas larger than Avatime.
4. For further information on the Avatime textile industry see E. R. Rado, *A Gold Coast Textile Firm* (University College of the Gold Coast, 1953) (Cyclostyled).

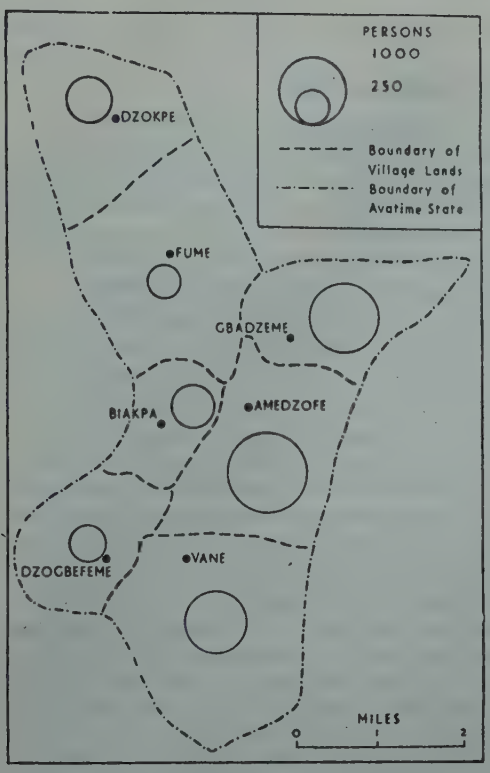

Fig. 4 Population of Avatime.

north. This area has been constantly expanding, especially since 1945. The indigenous population is sparse and expansion has been achieved mainly by immigrant labour, particularly from the overcrowded districts between Buem and the coast. No figures exist for this movement, but it involves many Avatime. They tend to congregate in certain of the new areas, going for the most part to Ahamasu, Kadjebi and Ayoma. These are in the newer areas of Buem, developed largely during the last ten years.

Avatime are found here both as farmers and labourers. Emigration may be seasonal or semi-permanent. The emigrant may return after each cocoa season or after a period of years. But in very few cases can the emigration be considered permanent. The particular Avatime village from which the emigrant comes is his 'home town', to which he returns to spend his money, to retire and for religious festivals.

There is, of course, no hard and fast rule, but a typical career of an enterprising emigrant may be summed up thus. As a young man he may work as a labourer or 'caretaker', returning to his 'home town' at intervals, until he has saved enough to start farming on his own account. He will remain on his cocoa holding until it has come into full bearing, that is, for about seven years. After that he may well leave it in charge of a 'caretaker', living in his 'home town' and returning to Buem only during the cocoa season.

While there is no means of ascertaining the exact number, a proportion of the 5,128 inhabitants of the last census would be directly dependent on cocoa holdings elsewhere. The number of inhabitants would also be at its annual maximum, for the census was taken in February, at the end of the cocoa season.

The cocoa belt of Togoland is not the sole outlet. Like the Ewe, many Avatime are to be found in Accra and other towns as clerks or teachers. Smaller numbers of more adventurous spirits find their way to the Ashanti cocoa areas and to the mines.

Thus is the life of the Avatime conditioned by their environment. In many respects the influences are those affecting all the peoples of southern Togoland. But these influences are increased in their effect by the rugged nature of the terrain in Avatime, which is unusual in West Africa.

CULTIVABLE LAND AND LAND USE IN EQUATORIA PROVINCE, SUDAN

By S. G. WILLIMOTT

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The question of the extent of cultivable land available for agricultural development in the southern Sudan has remained a problem which so far has received comparatively little attention. Different reasons can be assigned for this apparent neglect but the following are among the more important: the general backwardness and remoteness of the region, the absence of reliable agricultural data and statistics going back over the years, the demands of priority problems on the limited specialist staff available, and the frequent inadequacy of the small-scale maps. With these limitations, the relevant data must represent close approximations only in many cases but the main conclusions to be drawn remain valid. Nevertheless, such investigations take up time and effort and must await a favourable combination of circumstances. As a necessary preliminary to expanding research and development in the three southern provinces, and in Equatoria in particular, it was felt that the time was ripe to attempt some reasonably accurate assessment of the total land available for potential agricultural purposes and the present land use. This study was also stimulated by the selection of a district of Equatoria, that is Zandeland, for the inception of the Zande Scheme. This project was initiated by Dr. J. D. Tothill in 1945, with the objective of the social emergence of a primitive people and the economic stability of an under-developed area.[1] As development schemes expanded there appeared to be increasing necessity to obtain such information.

This survey was commenced in 1953 and intended originally to cover the whole of the province, but it soon became apparent that the practical difficulties would be too great. It was, therefore, decided to confine the study to the limit of Equatoria Province west of the River Nile, which in many ways was typical of equatorial Sudan. It was evident from the outset that official statistics of factors such as rock formations and outcrops, unmapped hills, rivers and streams, reserves for game and forests would not readily be accessible or easily computed. Even statistics on total land area and population justified critical scrutiny. However, in spite of these very real obstacles it was believed that, by a combination of reasonable approximations backed by first-hand knowledge of the district, it might be possible to arrive at some dependable conclusions. On the other hand, substantially accurate data were found to exist for categories such as townships,

1. With official endorsement from UNO, the term 'backward' has been abandoned in favour of 'under-developed'. 'Backward' involves subjective judgment; 'under-developed' is simply an objective statement and carries no stigma. Cf. L. D. Stamp, *Our Undeveloped World* (London, 1953), p. 49.

chiefs' courts, hospitals, dispensaries, sanatoria, mission stations, airfields and schools.

LEGAL ASPECTS OF LAND TENURE

The legal aspects of land tenure are related to the over-all question of land use and differ widely in the northern and southern regions of the Sudan. The question regarding the northern Sudan is dealt with in detail by Bolton(2),[1] whilst Guttmann(3) has recently studied the position of the Azande of Equatoria, and Nadel(4) the Nuba, who stand midway between the two. It will therefore suffice to give the main outline principally as it affects the south.

The settlement of rights to land and the registration of title to those rights are provided for in the Sudan by the *Land Settlement and Registration Ordinance, 1925*. By this ordinance, which consolidates previous legislation, all unregistered land is deemed *prima facie* to belong to Government. Nevertheless, in practice Government exercises its ownership in trust for the people who have habitually exercised rights over it; and Government has consistently refrained from interfering with any such rights, irrespective of whether they be communal or individual, in unregistered land.

From the viewpoint of land use and availability for agricultural purposes, it is necessary to treat the northern Sudan, almost wholly Arabic-speaking and in which Moslem Law applies, separately from the southern Sudan with its predominance of negroid pagan tribes. In the northern Sudan private ownership of land is common due to the prevalence of the Islamic religion and the recognition of private land-ownership by Moslem law. Registration of land, however, has been completed only in Khartoum and Northern Provinces and the area of the Gezira. In other provinces of northern Sudan registration appears to be confined to townships and does not include agricultural lands other than forest reserves.

In the southern Sudan practically all land is unsettled and there has been no registration apart from forest reserves and the towns of Juba and Malakal (5). The position of the individual tribesman in relation to the nominal landowner is, in the southern Sudan, defined by custom only. In the main it seems to be dependent on a political reciprocity, that is, of chief and tribesman, rather than on any reciprocity based on landholding. Consequently in Equatoria Province, where the available land greatly exceeds the agricultural needs of the sparse population, there is no individual ownership of land because the individual is regarded primarily as a member of his tribe. In Zande District the land is owned by the chiefs while other tribes in Equatoria own their land either communally or through a 'land father', that is, a descendant of an original conquering chief whose administrative functions have been usurped by the present chief's predecessors at some time in the history of the tribe. No problem of 'overlords', such as exists in the Rufa'a and Fung districts of the north, is encountered in the southern provinces. This briefly is the position of land tenure as it affects the south and the reasons may be summarized as follows:—

(a) There is no land hunger in the south; (b) the idea of individual ownership of land has not yet developed since land in the south has still to achieve an economic value; (c) the inhabitants are mostly pagan and, therefore, unaffected by the recognition given to individual ownership of land under Moslem Law; (d) the doctrine of Government trusteeship has never been challenged.

AREA AND POPULATION

For administrative purposes the province of Equatoria is divided into six districts, each in charge of a District Commissioner:— Eastern, Torit, Juba, Moru,

1. Figures in brackets in the text refer to the numbered references on p. 50.

Yei and Zande, which again are split up into a number of sub-districts. For this survey the province was divided into the areas lying respectively on the western and eastern banks of the Nile; and, as already indicated, only the area west of the Nile has received detailed study.

Equatoria Province has undergone several frontier changes in its history. In 1935 Bahr el Ghazal Province was amalgamated with Mongalla to form a new Equatoria Province, and again separated in 1948. The fact that official statistics, given in the Sudan Almanac of 1955 (3), may be at variance in certain particulars with those listed in Tables 1 and 2 is explained by minor frontier revisions on the old Survey map. However, the statistics quoted in this paper may be regarded as the most accurate available. It is noteworthy that the first complete population census is to be completed by 1956.

Data for areas and population of the province lying respectively on the east and west banks of the Nile are summarized in Table 1.

TABLE 1: EQUATORIA PROVINCE: AREAS EAST AND WEST OF THE NILE

AREA	SQ. MILES	FEDDANS	POPULATION	POPULATION DENSITY (PER SQ. MILE)
EAST OF NILE	31,426	19,370,986	223,150	7·1
WEST OF NILE	45,069	27,780,532	409,969	9·1
TOTAL	76,495	47,151,518	693,119	—

1 sq. mile = 640 acres = 616·4 feddans.

These figures reveal the comparative sparseness of the population but show a definitely higher density for the area west of the Nile, a conclusion in harmony with experience. It is noteworthy that certain areas in the province, on both banks, appear to be almost wholly depopulated; as, for example, the area lying between the Kathangor massif and the Boma and Lomarang Plateaux (Eastern District) and the north-western part of Zande district on the west bank known as Qos Dengwir (4). Such areas remain for the most part unsurveyed and unknown and are given over to the wild life found there in such great numbers and variety. There are no cultivations or homesteads and only occasionally are nomadic tribes encountered.

The Province of Equatoria west of the Nile comprises the four administrative districts of Juba (part), Moru, Yei and Zande with their respective sub-districts. As part of the Juba district lies on the east bank, this area was computed by planimeter from the Survey maps and deducted from the total. The latest available data, consolidated from all sources, are given in Table 2, together with the estimated present population.

TABLE 2: EQUATORIA PROVINCE WEST OF THE NILE: AREA AND POPULATION

DISTRICT	SQ. MILES	FEDDANS	POPULATION (APPROX.)	POPULATION DENSITY (PER SQ. MILE)	ADMIN. H. Q.
JUBA	7,503	4,624,849	63,000	8·4	JUBA
MORU	13,800	8,506,320	67,200	4·9	MARIDI
YEI	6,232	3,841,405	111,400	17·9	YEI
ZANDE	17,534	10,807,958	168,369	9·6	YAMBIO
TOTAL	45,069	27,780,532	409,969	—	—

These statistcs reveal the fact that Yei is clearly the most populous district and Moru the least. About sixty per cent of the area of Juba district lies to the west of the Nile and, being more developed, shows a somewhat higher population density than the east-bank area. Of the remaining two districts Zande shows a density almost double that of Maridi. Examination of the statistics for past years indicates a tendency towards a small annual population increase. The population of Juba town, the province headquarters, is given as 18,500 and is steadily increasing.

CLIMATIC AND SOIL CONDITIONS

The climatic and soil conditions of Equatoria Province, east and west of the Nile, reveal some differences which are contrasted for convenience in the following table.

CLIMATIC AND SOIL CONDITIONS ON THE EAST AND WEST BANKS OF EQUATORIA PROVINCE.

	East Bank	West Bank
TOPO-GRAPHY	Varied with high mountain ranges and extensive clay plains. Rivers become wadis in dry season.	Generally undulating and rolling. Dissected lateritic peneplains with granitic inselberge and intrusions. Larger rivers flow throughout dry season.
SOILS	Varied with much heavy, cracking, alkaline clay. Some volcanic soils and alluvium. Much kankar (calcium carbonate concretions) is encountered. In general soils are of higher inherent nutrient status than those of west bank. Often transported.	Latosols. Pea-iron gravel usually dominates the profiles. Soils acid. In general, of low inherent nutrient status but certain loams in Yei and Zande districts have considerable cropping capacity. Mostly *in situ*.
RAINFALL	From 35-45 in., except on the high mountain ranges, e.g., Imatongs and Dongotonas. Not well distributed.	Up to 60 in., falling off to the north and towards the Nile. Often unevenly distributed.
TEMPER-ATURE	Temperatures generally tend to be higher than in the west. Taking Torit as typical of the area: mean daily temperature is 80·5°F. Mean daily maximum temperature ranges between 86·9° and 99·9°F. Mean daily minimum temperature ranges between 64·8° and 70·0°F.	Taking Li Yubo as typical of the area: mean daily temperature is 76·5°F. Mean daily maximum temperature ranges between 81·7° and 91·8°F. Mean daily minimum temperature ranges between 65·3° and 67·6°F.
DRY SEASON	Tends to lengthen in eastern parts to between 4 and 5 months.	Usually about 3 months.

AGRICULTURAL SYSTEMS AND LAND USE

Most of the agriculture of the Sudan is on a subsistence basis and this is particularly the case in the southern Provinces with their shifting cultivation and bush-grass fallow. The most superficial experience of the south shows it to be no eldorado. Both economically as well as agriculturally it is a problem region and has been well described as 'the mull area' of tropical Africa. In spite of much thought and trial it remains today one of the most intractable regions of the tropics. The reasons are not hard to seek.

The soils generally are of low intrinsic fertility. It is a region of no fertilizers, little animal husbandry and no available animal manure. Crop production is entirely dependent on the rainfall and there is at present no irrigation. Its remoteness and lack of good communications impose heavy obstacles in the way of development. There is an absence of markets and little incentive for the production of crop surpluses. Mechanized agriculture is unknown and all agricultural operations fall to the lot of human muscles. Last but not least is the human factor. The native population, indolent and feckless by nature, still labours under chronic infections which rob them of vigour of mind and body to the exclusion of all initiative and drive. With this unpromising background it is seen that the only two natural assets which suffuse the situation with some hope are the abundance of cultivable land and the rich natural tree cover that protects it from leaching and erosion.

With an almost limitless potential of cultivable land to the head of population, the system of shifting agriculture, or 'leaving it to nature', follows logically. In this system a plot is brought under cultivation for about three years and then the peasant shifts to new ground, usually virgin bush. The land is abandoned when the crop yield collapses or when the invasion of perennial speargrass (*Imperata cylindrica*, Beauv.) sets in. In the wetter areas regeneration of vegetation in the fallow is extremely rapid and effective.

The move to new land involves clearing an adjacent area of bush and so the process continues until the original plot has regained by natural regeneration its original fertility and is once more brough back into cultivation. The first crop sown to clean the land is often groundnuts, sesame or maize, to be followed by eleusine. Inter-cropping is the rule. Before abandoning an area to bush-fallow a subsidiary crop may be sown, or more often cassava (bitter and sweet) will be planted and may remain in the ground for from three to four years. This is an important development in the South where the invasion of the bush-fallow by cassava is now producing an exportable surplus which is becoming increasingly economic.

The system of shifting agriculture has advantages and disadvantages. Following upon soil exhaustion through continuous cropping the cultivator simply leaves the plot to return to bush or grass until it regains most of the fertility lost. It thus avoids the labour and expense of green manuring. Moreover, for small separated plots the damage caused by pests and diseases is minimized. Shifting agriculture, with a resting period of anything up to twelve years, is in effect a modified form of crop-rotation with a long resting period. The great disadvantages are its wastefulness, requiring as it does about five times as much land as is needed by modern methods, and the small units involved. With the present population density this constitutes no immediate problem. Only one fifth of the total cleared area is under crops at any one time, the remainder being in different stages of natural regeneration.

Inherent in the system is the practice of the annual burning of the bush. Even when confined to the organized, early burn of the cool season, because of the damage by soil erosion, leaching, and hence loss of fertility, the practice has little to recommend it. When carried out later in the dry season the fierce fires and high flames inflict permanent damage, which is cumulative both to soil and vegetation. Not only is valuable humus destroyed, but phosphate and sulphur must also be lost by volatilization through the high temperatures reached. Aerial photographic reconnaissance has shown that over extensive areas in the south almost complete denudation has resulted from uncontrolled burning. Even at 15,000 ft. observers have recorded the presence of large specimens of carbonized vegetation caught up in the extensive air turbulence generated. There are solid grounds for believing with Jewitt (7) that the annual grass-fire transforms the traditional native system into a rotation of cropping followed by cropping-by-burning. It is sometimes not appreciated that the long-continued practice of the annual burn has also had the effect of suppressing all but the fire-resistant species of tree and grass and so of virtually transforming the main character of the standing flora.

As regards the staple crops, it will suffice to state that cotton is the cash crop with chillies a poor second and the rest affording subsistence foods. On the west bank Zandeland is the centre for cotton production and on the east bank Torit. The principal cereals on the west are eleusine (*Eleusine coracana*, Gaertn.) and maize with a little dura (*Sorghum vulgare*, Pers.) in the drier zones. Dura predominates in the drier parts of the east bank. Groundnuts are common everywhere the soil and rainfall permit cropping. Cassava is important and increasing, especially eastwards, and has already invaded the bush-fallows. Sesame and native varieties of beans, especially in the west, complete the pattern of agricultural land-use.

The predominance of tree crops — mangoes and citrus — is a distinguishing feature of much of the province west of the Nile. This is all 'fly' country so that animal husbandry is almost unknown. On the other hand, the Tapousa of the east bank are herdsmen as well as cultivators in a small way.

TREE CROPS

Most observers in Equatoria have remarked on how little land appears to be cultivated compared with the vast area of virgin bush. Clearly the area under cultivation offers no clue to the total area that could reasonably be regarded as available for agricultural development of all kinds. From this standpoint, as we have already seen, the only real capital asset in Southern Sudan is land and the only insurance against erosion, leaching and loss of soil fertility is the natural cover of the broad-leaved woodland.

A host of soil problems arises as soon as the bush or grass cover is cleared and the soil exposed. Fortunately, in spite of the savage system of the annual burn, nature still succeeds in the struggle to conserve soil structure and fertility by means of the standing tree-cover. The reason is that trees are able to take care of their own soil needs and nutrient requirements. Trees are so much better adapted to utilize rainfall when it comes than annual crops. They can utilize soil moisture far better than annuals because of their deeper root system and their power to search for moisture. The mosaic of the leaf canopy is able to break up the actual falling raindrops of tropical storms when three inches or more may fall in a single storm, thus preserving soil structure and minimizing leaching. Trees are far better equipped to withstand the drought of a dry

season or the short intercurrent droughts of the wet. They hold the soil in position and counteract erosion. Tree crops, once established, require less care and maintenance and are in fact a feature of permanent agriculture. They may be considered equally for the hill or the plain.

The purpose of the above discussion is to suggest that suitable tree crops should be built into the structure of land use in Equatoria and developed on the scale of plantation agriculture. The possibilities for economic tree crops, efficiently established and well managed, offer the best solution of the major problem of soil fertility. Admittedly there are difficulties to be overcome but perhaps none of them are really insuperable. The potentiality of plantation agriculture has never yet been tried out in Southern Sudan. Here it is not necessary to elaborate details because it is with principles that we are mainly concerned. Africa is changing rapidly, and the tribes are beginning to look to new horizons. Perhaps by changing the outlook it may be possible to accomplish here in the future what has already been done in neighbouring territories with closely similar backgrounds. To some the idea of tree crops may represent a new, perhaps revolutionary, concept in present land use and agronomic practice but this should not constitute an objection if such projects offer practical solutions.

One of the tantalizing aspects of native agriculture in the south is that almost any tropical or sub-tropical crop will grow but never quite at the yield-level to influence world markets. But for plantation cropping by modern techniques the following tree crops can be legitimately considered:— oil-palms, coffee, citrus, tea, sugar-cane and edible nuts such as pachira (*Bombax sessile*, Benth.) and cashew (*Anacardium orientale*). If successful, such tree crops could render the Sudan economically self-sufficient in staple foodstuffs, with the retention of millions of pounds of foreign exchange at present going out of the country. The difficulty is that many of these possibilities can never become economic realities, thereby lifting the standard of living significantly, unless they are developed on the larger scale associated with land use in the plantation system.

Lastly, geological surveys up to date lend little support to the popular belief in the existence of economic deposits of minerals, oil or coal: consequently the prosperity and future of the Southern Sudan must inevitably turn on the exploitation of its agricultural and forestry resources.

AVAILABLE CULTIVABLE LAND

It now follows that, in order to be in a better position in future soil-survey work to assess the extent of any recognized soil type for a particular crop in relation to the total cultivable land, it becomes a matter of some importance to have such information readily available. For this purpose, it was obvious that certain categories of land must for practical purposes be regarded as lying outside the scope of future agricultural development. Such areas were deemed to include the categories listed in Table 3.

TABLE 3: EQUATORIA PROVINCE: LAND NOT AVAILABLE FOR AGRICULTURAL PURPOSES

CATEGORY	FEDDANS	REFERENCE
HIGH LAND (INCLUDING INSELBERGE) WITHOUT PROTECTIVE COVER AND USUALLY ERODED	792,960	CALCULATED FROM SURVEY MAPS.
ROCKY OUT CROPS INCLUDING MUNGAS[1]	415,708	COMPUTED AT 1¼% OF TOTAL AREA
FOREST RESERVES	316,273	FORESTRY DEPT.
GAME RESERVES	1,970,000	GAME WARDEN'S DEPT.
TOWNSHIPS AND VILLAGE AREAS	18,147	DISTR. COMMISSIONERS.
ROADS	23,623	SURVEY DEPARTMENT.
RIVERS AND STREAMS	55,685	SURVEY DEPARTMENT.
CIVIL AIRFIELDS	254	CIVIL AVIATION BRANCH, MINISTRY OF THE INTERIOR.
HOSPITALS, DISPENSARIES AND SANATORIA	8,663	MINISTRY OF HEALTH.
SCHOOLS, GOVERNMENT AND MISSION	1,977	MINISTRY OF EDUCATION.
MISSION STATIONS	3,550	C.M.S. AND V.F.M.
CHIEFS' COURTS AND COMPOUNDS	149	DISTR. COMMISSIONERS.
TOTAL	3,606,989	

Estimates of the total areas falling into these different categories were obtained by computation from information supplied by courtesy of the different Government Departments or authorities concerned, by planimeter measurements of the relevant survey maps (1:250,000), or by arbitrary calculations based on first-hand knowledge of particular areas. In Table 3 are summarized the approximate areas, in terms of feddans, falling into these different categories respectively.

The regions of high land were computed from the Survey maps by measurement of the areas outlined by form lines above the general lie of the surrounding terrain. These areas were obtained by the aid of tracing and squared paper, in each case a uniform marginal zone being allowed around each hilly district marked on the map, to take into account high land not susceptible to cultivation. Wherever possible these areas were confirmed by reference to Sudan Government vertical air-photography. The total figure is perhaps smaller than might have been anticipated but is accounted for by the general undulating character of the country.

Towards the French Equatorial Africa frontier a group of hills has been discovered in this survey, which as yet has not been ground-surveyed nor recorded on any existing survey maps. For an approximation of the area of this high land in Qos Dengwir, thanks are due to Mr. J. F. R. Lushington, Assistant Conservator of Forests and to Mr. T. Lister, Inspector of Agriculture, who in 1954 surveyed this area on foot; also to Mr. P. E. T. Allen, of the Survey Department, who supplied air-photographic interpretations of this region. From air-photographic survey it appears that this area is extensive, contains a number of peaks, is covered in parts by thick forest, and is dissected by several gallery forests. This terrain, which extends to about 50 sq. miles, has been scheduled by the Survey Department for further detailed examination.

1. *Munga* is the Zande term for a lateritic outcrop characterized by mushroom-shaped termitaria and distinctive grasses.

In addition to the known high land, many bare rocky areas exist which seem to increase in frequency towards the drier northern zone of the Province. These formations have the characteristic appearance of a whale's back, are black in colour and quite distinct from the lateritic *mungas*. By agreement with field and survey officers with experience of the region, these areas were taken to represent not less than 1½% of the total surface area of Equatoria west of the Nile. It should be noted that, with negligible exceptions, land falling under the remaining heads given in Table 3 lies outside the 'high land' category.

The total for forest reserves included areas already gazetted, together with areas surveyed and awaiting reservation. In West Equatoria this includes two forest districts, viz., Central and Zande Circles. The long-term policy of the Forestry Department is to increase the present area so as ultimately to have from ten to fifteen per cent of the total area of the region under reservation.

The total area of the National Game Reserve in southern Sudan is four million feddans. This big reserve extends into Equatoria at two points, i.e. (a) in the Jebel Angeleri district, and (b) in the area between the rivers Ibba and Sue. The area of the reserve lying in Equatoria is about two-fifths of the total figure, i.e., 1,970,000 feddans.

As regards townships, the only two with demarcated boundaries are Juba (4,338 feddans) and Maridi (532 feddans) with an overall estimate of 5,381 feddans for Nzara Urban District.

The road system is under the control of the Public Works Department so far as all-weather roads are concerned; and under the control of the District Commissioners for all others including tracks. The total length of roads and tracks is over 8,500 kilometres whilst the width of the roads varies from five to ten metres according to the class of road and district.

The assessment of the area taken up by rivers, streams and *khor*[1] presented a thorny problem. In conjunction with the Survey Department, it was estimated from the maps that the total length of the main rivers of the region totalled 1,675 miles, with an average width of 30 yards. From a study of the larger-scale Survey maps (1:100,000), air photographs, and a close acquaintance with the region, it was agreed with the Survey Department to allow for an equal area to cover streams, rivulets and *khors*, giving a grand total under this head of 55,000 feddans. No lakes of any size or permanent swamps occur in the Province.

Estates represented by agricultural institutions such as the Yambio Experimental Farm, the Agricultural Training School, Yambio, and the Forestry Station, Kagalu have been regarded as cultivable land.

CONCLUSIONS

From the statistics given in Table 4, it is seen that high land and rocky outcrops account for roughly 1·2 million feddans and that another 2·3 million feddans are accounted for by the different reserves. The official area of Equatoria west of the Nile is 27,780,532 feddans. Deducting the grand total of land not available for agriculture, i.e., 3,606,989 feddans, leaves a figure of 24,073,543 feddans, or approximately 87 per cent. In the Zande district, with a total of 36,000 poll-tax payers, it has been calculated that there is an average of 187,500 feddans under cultivation and fallow in any one year for a total

1. *Khor* (pl. *kheiran*) is the Arabic term for a large stream. In Equatoria it denotes such a stream, usually perennial and with gallery forest lining the banks. but in the North Sudan a *khor* is always a seasonal water-course.

population of 168,369, which of course includes men, women and children. On this basis, we arrive at a figure of 456,550 feddans under cultivation and fallow for the whole region under survey. Admittedly this estimate is based on the assumption that the amount of land cultivated annually is the same throughout the region. Considering that the Zande district is probably the most cultivated area in the Province, because of its rather better soils and good rainfall and the necessity for raising the cash crop of cotton required by the Equatoria Projects Board (E.P.B.) mill at Nzara, the total cultivated area of Equatoria west of the Nile is not likely to be higher, and might well be lower, than this estimate. Thus only 1·6% of the total land area can be regarded as actually under cultivation in any one year. It is instructive to compare these data with those compiled by Mr. W. A. Davie (6) for the period 1905-21, comprising the whole of the Sudan at that time. Taking the whole area of the country at 640 million feddans, the total cultivated represented 1·796 million feddans, or only 0·3% of the whole.

Since published agricultural data in Equatoria are so meagre some recent information on areas under crops of economic importance in Yambio Sub-district for two seasons is given in Table 4 below. For many of the agricultural data relating to Zande district I am indebted to Mr. T. A. T. Leitch, Senior Inspector of Agriculture, E.P.B., Nzara.

TABLE 4: ZANDE DISTRICT: AREA UNDER ECONOMIC CROPS

SEASON	1951-52 (FEDDANS)	1952-53 (FEDDANS)
ESTIMATED NUMBER OF CULTIVATORS	18,500	18,500
COTTON	9,382	8,775
GROUNDNUTS	5,629	5,474
SESAME	509	672
ELEUSINE	8,000	8,000
TOTAL	23,520	22,921

INDIVIDUAL CROP YIELDS WERE NOT INCLUDED AS THE DATA WERE INCOMPLETE

The vast area of land remaining for cultivation in west Equatoria represents 87% of the total, of which less than 2% is under cultivation. The proportion of the total land available for development is not altogether surprising and affords the agriculturist some practical idea of what area, given favourable economic and social conditions, is capable of being expanded for food and other economic crops. Truly there is no land hunger in Southern Sudan. At a later stage, when a systematic survey of the main soil types for crop production has been completed, this information can provide the common denominator for calculating the percentage of available agricultural land falling into any particular category of soil type.

COMPARATIVE DATA ON LAND USE

It is useful to compare the information obtained in the study of a comparatively restricted area of equatorial Africa with the pattern of land use on a world basis and in the Far East. In Table 5 are summarized data relating to world land use in 1949 and 1930 respectively.

TABLE 5: WORLD LAND USE

		ACRES	SQ. MILES (MILLIONS)	PERCENTAGE
FAO (9)	ARABLE OR CROPPED	3,006	4·7	9·1
	MEADOW AND PERMANENT PASTURE	5,269	8·2	15·9
	FOREST AND WOODLAND	8,702	13·6	26·3
	UNUSED BUT POTENTIALLY PRODUCTIVE	936	1·5	2·8
	BUILT-OVER, WASTELAND, AND OTHER	15,200	23·7	45·9
	TOTAL	33,113	51·7	100·0
C. B. FAWCETT (10)	CULTIVABLE			30·0
	FOREST, POOR GRAZINC, HILL PASTURE & BUSH			30·0
	DESERTS, DRY AND COLD			40·0
	TOTAL			100·0

From these statistics it is seen, in the case of the FAO data, that only 2·8% of the total land is considered potentially available for further development although some fraction of the 45·9% of wasteland might reasonably be brought into cultivation. Professor Fawcett considered the 30% cultivable fraction, which included the tropical rainforests, as offering the chief possibilities for extension of cultivation.

The position affecting land use in a developed and prosperous territory of the Far East presents a different situation. Taking Malaya as a country typical of South-East Asia, some data obtained by the author in a study of land use in 1949 (11) showed that of a total area of 32,537,600 acres, 50·6% was available for agriculture, of which 16% was already in cultivation. A comparison of the data obtained in this study with those for Malaya and the world emphasizes the present under-developed character of Equatoria, a territory typical of Southern Sudan, and the possibilities for future agricultural expansion. Only upon the solid foundation of agriculture can the future prosperity and advancement of the southern provinces of the Sudan be realized.

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COMMUNICATIONS IN FRENCH WEST AFRICA

By A. SECK

Translated from the French by Nora Toupet.

Communications are in all countries one of the most important factors in economic development. In the interior of French West Africa their inadequacy constitutes a very serious obstacle to such development. It is noticeable that nowadays the most progressive regions of French West Africa are the coastal regions, that is, those where communications are best developed. On the contrary, the interior regions remain isolated and economically backward.

This deficiency in modern means of communication hampers very seriously the interior regions. It is true that there are several important rivers but often they are encumbered by rapids. The two great rivers (the Senegal and the Niger) traverse several structural basins at the edges of which rapids are formed. Still, on the Senegal and the Niger the intervening smooth reaches are long enough to permit some local navigation; whereas the rivers of the Gulf of Guinea, like the Sassandra, the Bandama and the Comoé, are so encumbered that their smooth reaches are without any importance. Only the rivers of the Senegal depression escape this defect, but they are not very long and thus they are of no service to the interior. Thus, the natural routeways are incapable of breaking through the isolation of the interior regions.

As for artificial routeways, despite the efforts that have been made they are still hopelessly inadequate. The longest railways were planned to connect the navigable reaches of the two biggest rivers. But only the Kayes-Niger and the Conakry-Niger have achieved this object, the Bénin-Niger not being finished and the Ivory Coast not having established the branch-line which, leaving from Bobodioulasso, should have reached the Niger. Elsewhere the difficulties of navigation on the River Senegal, and the absence of a large sea-port at its mouth have stimulated the construction of the trunk line from Dakar to Kayes, so that the products of the Sudan reach Senegal exclusively by rail. Thus, generally speaking, the railways into the interior are inadequate and occur only in the form of trunk lines without branches or feeders. Nevertheless, they could play an important part in the economic development of the interior if they were supplemented by a good network of roads. But French West Africa has no good roads. It is said that there are 100,000 kms. of roads, but as a matter of fact modern roads are limited to the coastal regions and the immediate neighbourhood of the towns. Everywhere else there are simply tracks passable only in the dry season, and footpaths through the bush. Thus, French West Africa is divided into two large areas very different from each other:

(1) the coastal regions by which Europeans entered the country and which, already favoured by the proximity of the sea, by the navigable lower courses of rivers, and sometimes by the presence of lagoons, receive the largest share of capital equipment (roads, railways with branch-lines, and the few processing industries which are to be found in French West Africa). There, too, European trade is most active.

(2) the isolated interior regions where access to the sea is difficult. These regions, nearly all of them on the savanna lands (interior of Senegal, High

Guinea, Sudan, interior of the Ivory Coast, interior Volta, Niger) are not lacking in economic potentialities. First, this is the most favoured zone for cattle-breeding; then, all the types of farming common in Senegal can be practised there and in particular the ground-nut might become an important crop. Geological exploration, although in its infancy, already reveals the presence of important quantities of tin in the district of Air. Finally, and above all, these regions are the richest in men. Unfortunately these potentialities have not yet been realized, owing to the absence of adequate means of communication: all the regions remote from railways and navigable stretches of the Niger are little developed, at least as far as export crops are concerned. The result of this is insufficient traffic for the railways, which makes the cost of carriage very high, and only a few products of great value and little weight (cotton, karité-butter, etc.) can justify transport by rail. For other products, transport is possible only because they yield a very small profit to the producer. Under these conditions, it is probable that if the population were not

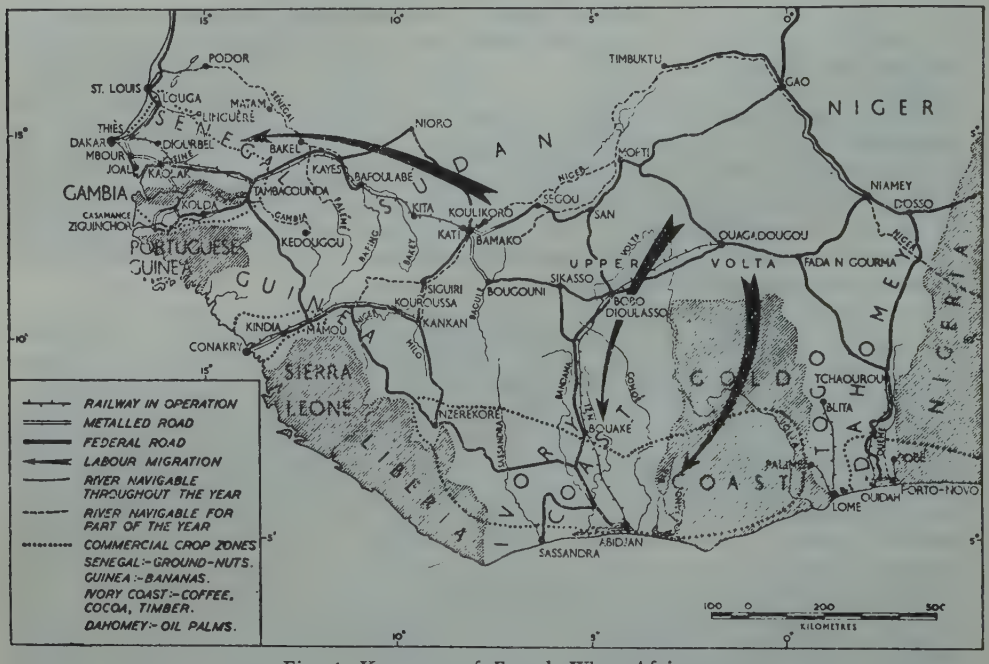

Fig. 1. Key map of French West Africa.

obliged to pay taxes in cash, many villages would have contented themselves with maintaining their ancient system of closed economy. The former economic stability of the villages is today broken, and the payment of taxes in cash compels the peasant to direct part of his activities towards the production of sufficient cash crops to meet this demand. In fact, the peasant, with his primitive methods of production, and working hard throughout the year to gain a precarious livelihood, cannot engage in commercial production except to the detriment of his own food supplies. Moreover, owing to the difficulties of transport, commercial crops yield little profit and, when taxes have been paid, practically nothing is left to the peasant of the interior, whereas the coastal peasant still possesses a certain amount of money. It is, then, easily understandable why most villages of the interior find themselves in a difficult situation, perhaps more difficult than in former times. Now, although the movement of crops is difficult, the migration of persons

and ideas is much easier than formerly, first, because of increased security; then because of the introduction of the bicycle which can use the footpaths in the bush; because of the automobile which uses the tracks in the dry season, because of the train which one can take at Ouagadougou, at Bamako or at Kankan, and because of the aeroplane which brings news from the more fortunate coastal regions. Because of all that, if the older farmers yet retain some attachment to the soil, the young ones respond more and more to the appeal of the coastal regions and of the towns, where they find it possible to earn more money. That is why every year thousands of *navetanes* coming from the Sudan and High Guinea invade Senegal to engage in groundnut cultivation, while the inhabitants of the Haute-Volta troop down towards the plantation-lands of the Gulf of Guinea. Some of these young people return to their countries when they have accumulated a little capital, but most of them are definitely lost to their villages. This selective emigration, if it continues, may well undermine all prospects of development in the interior regions, first by seriously diminishing the supply of labour and then by causing a dangerous decline in the birth-rate.

This marked difference between the coastal and interior regions is, doubtless, a consequence of the trade-economy which seeks a maximum of profit for a minimum of risks. It is irrational, indeed, but of immediate profit to concentrate nearly all available effort and equipment in the coastal regions to the detriment of the interior regions. Still, one must avow that there are enormous difficulties in the construction of a modern network of communications in the interior regions: first, the average density of population is low (5 to 10 per sq. km. for the whole of the non-desert regions) and, apart from the desirability of connecting the several territorial capitals, no particular region seems to be able to establish undisputed claims of priority. Furthermore, the capacity of such routes to pay their way is far from being assured in the immediate future. There is thus established a vicious circle, from which it seems difficult to escape: without a minimum degree of economic development there can be no profitable means of modern transport; and without modern transport no rational economic development is possible.

The Government of French West Africa, appealing to the solidarity existing between all the regions under its administration, last year proposed an ingenious system: the national railroad companies would be granted subsidies which would reduce the cost of transport in the interior regions. This would in turn allow the farmers higher profits, thus acting as an inducement to young people to remain on the land and also as a stimulant to the peasants to produce more. To complete this cycle, the railways would find their profits increasing from the transport of this extra production, and would eventually no longer require the subsidy. Thus everybody would profit by this system: the peasant would earn more money; the territories would pay more taxes and retain young people; and the railroads would balance their budget and perhaps even make profit.

This system is ingenious indeed; unfortunately its full effect will be experienced only by places close to the railway. It seems to us also that the processing of local products in these interior districts would be a valuable stimulus to economic development: first, a great deal of the profit from these industries would remain at the point of production, because local workers would be employed. Then, the peasant would receive more money, because he would not have to pay for the transport of waste products. And if discriminatory prices were paid according to the quality of the products, there is no doubt that the peasant, with his usual good sense, would at last be induced to modify his traditional methods of work in order to earn more money. Moreover, the finished products, being of

greater value, would justify longer rail hauls. Finally, transport of more valuable products would permit the construction of a network of self-supporting roads or railways. And this network of communications and processing industries would constitute a framework within which a stable population would develop.

Doubtless it will be difficult to find the necessary capital; the average income of the African being about 20,000 frs. CFA (£40 sterling) per year. Still, not only could the subsidies to be given to the rairoads constitute an initial share of capital, but one might also appeal to metropolitan capital and even foreign capital.

But all this is a theory indubitably difficult to put into practice. Our purpose here is less to present a final solution than to draw attention to the gravity of this transport problem in the interior regions of French West Africa. Considering that the Sudan regions were formerly the most prosperous and developed parts of French West Africa, one may legitimately ask whether the systematic orientation of their economy towards export is not the fundamental fact influencing their decline. If that is so, prosperity can only be restored to these regions by utilizing their resources for themselves and not mainly for metropolitan needs. Fortunately the actual formula of union between France and its Overseas Territories seems to point in this direction.

CLIMATE IN THE SOUTH-EAST QUADRANT OF CEYLON

By RUDOLPH WIKKRAMATILEKE

INTRODUCTION

In Ceylon, seasonal changes in temperature are slight and are of little significance as a climatic factor.[1] Diurnal ranges of 15°F to 20°F are however experienced in many parts of the island and there are also differences in temperature dependent on variations in relief and altitude.[2] An account of the climate of the island, therefore, resolves itself mainly into an analysis of the seasonal distribution of rainfall brought about by the seasonal changes in atmospheric pressure and associated wind circulations, with due consideration to the modifying effects of relief on rainfall.[3]

The dominant factor influencing the distribution of rainfall over the island is the monsoons. Two monsoons, the north-east and the south-west, are experienced during the year. Consequently, the seasonal sequence of climate in Ceylon is interpreted in terms of these two monsoons as follows:—

November — February - - -	period of the north-east monsoon.
March — April - - - -	intermonsoon period.
May — August - - - -	period of the south-west monsoon.
September — October - - -	intermonsoon period.

(I) Rainfall

During each season, the rainfall over the island may be of one or more of the following types: orographic, convectional, depressional and frontal.[4] There are significant variations in weather conditions and especially in the distribution and intensity of the rainfall between one season and another at all stations for which statistics are available, and also from place to place during any one season.[5] These variations depend on a number of factors among which are the strength and direction of the winds, the degree of relief, the extent of the area over which the wind systems operate and the type and intensity of the rain.[6]

1. Ceylon has an area of 25,332 sq. miles. It is located between 5° 55'N and 9° 50'N latitude, and between 79° 42'E and 81° 52'E longitude.
2. In the central highlands, which cover about 4,000 sq. miles, elevations range from 1,000 ft. to a maximum of 8,281 ft.
3. For a treatment of the seasonal distribution of pressure and wind circulations see; A. J. Bamford, 'Notes on the Climate of Western Ceylon', *Ceylon Journal of Science*, Sect. E, vol. 3 (Colombo, 1929), pp. 173-207; and G. T. Thambyahpillay, 'Climatic Controls in Ceylon', *University of Ceylon Review*, vol. II, No. 4 (Colombo, 1953), pp. 1-10.
4. R. D. Kreltszheim, 'Rain Clouds and Rain in Ceylon', *The Tropical Agriculturist*, vol. 103 (Colombo, 1947), pp. 26-33; and A. J. Bamford, 'Cyclonic Movements in Ceylon', *Ceylon Journal of Science*, Sec. E, vol. I (1926), pp. 15-37.
5. On the island rainfall is recorded at 515 stations. All statistics in this paper, unless stated otherwise, are from the *Annual Reports of the Colombo Observatory*, Department of Meteorology, Colombo.
6. G. T. Thambyahpillay, 'The Rainfall Rhythm in Ceylon,' *University of Ceylon Review*, vol. 12, No. 4 (1954), pp. 1-50.

The island as a whole receives a higher proportion of its rainfall during the north-east monsoon.[1] During this period few parts of the island receive less than 20 in. of rain (Fig. 1). The ascent of air over the smaller relief gradient on the north-east flanks of the central highlands (Fig. 2), results in only partial condensation of the moisture content of the air to windward. Much rain falls to leeward over the south-western and western parts of the island as well, when the descending north-east wind is forced to rise once more on meeting local convectional winds. Furthermore, as the following figures show, cyclones are more frequent during the north-east monsoon and these bring rain to nearly all parts of the island.

AVERAGE FREQUENCY OF CYCLONES FOR CEYLON[2]

Month	J	F	M	A	M	J	J	A	S	O	N	D	Year
NUMBER OF CYCLONES	3	0	3	3	2	0	1	0	2	10	19	5	48

The rainfall during this period is extremely variable, and the occasional failure of the north-east monsoon rains is associated with not only the changeable north-east wind but also with the variation and the frequency of the cyclones from one year to another at this season.[3]

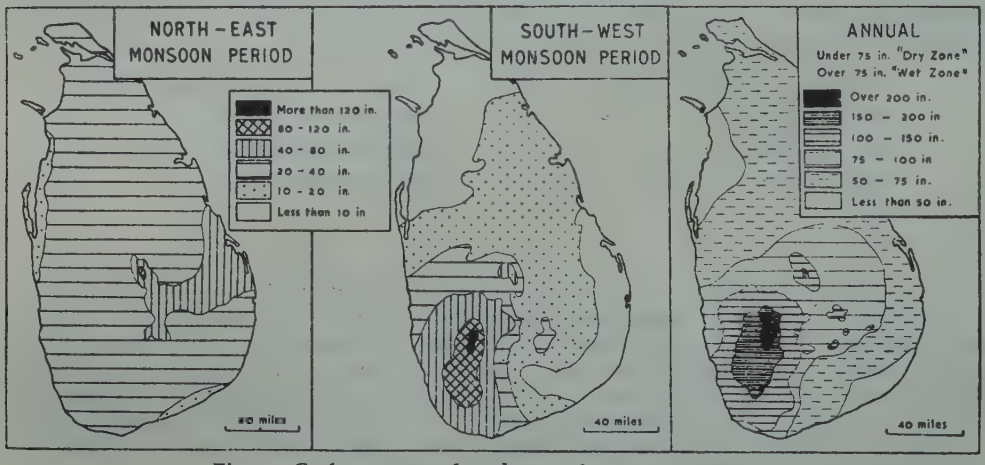

Fig. 1. Ceylon: seasonal and annual average rainfall.

During the south-west monsoon the distribution of rainfall is less uniform than during the north-east monsoon, and the rainfall is confined mainly to the windward sectors of the highlands and to the south-western parts of the island (Fig. 1). Little rain is carried over to the northern, eastern and south-eastern parts of the island and long periods of drought usually occur in these parts of the island. The south-west winds are forced to ascend rapidly over the stronger

1. L. A. D. I. Ekanayake, 'Some Observations on Climate and Weather in Ceylon', *Bulletin of the Ceylon Geographical Society*, No. 2 (Colombo 1945), pp. 7-11; and S. J. Bocks, *A Statistical Analysis of Rainfall in Ceylon*' (Library Research Laboratory, Department of Irrigation, Colombo).
2. A. P. Kandasamy, 'Tropical Cyclones and their Effect on Ceylon Climates,' Bull. *of the Ceylon Geog. Soc.*, vol. 3 (1948), p.6.
3. H. Jameson, 'The Northeast Monsoon Rains of Ceylon', *Ceylon Journal of Science*, Sect. E, vol. 11 (1936), pp. 27-34.

relief in the south-west of the island and this induces heavy rain to windward of the highlands. To leeward the descending winds, known locally as the *kachan*, are strong and dry.[1] The small number of cyclones during this period is also a contributory factor to the marked regional concentration of rainfall during the south-west monsoon.

During the intermonsoon periods much of the rain is convectional. It is highly unpredictable. Thunderstorm activity is usually confined to a few days in each month. The area affected by each storm is relatively small, consequently one district might receive a high precipitation from several storms at this season, while a neighbouring district normally as wet might get very little rain. In October the convectional rain is supplemented by rain from cyclones.

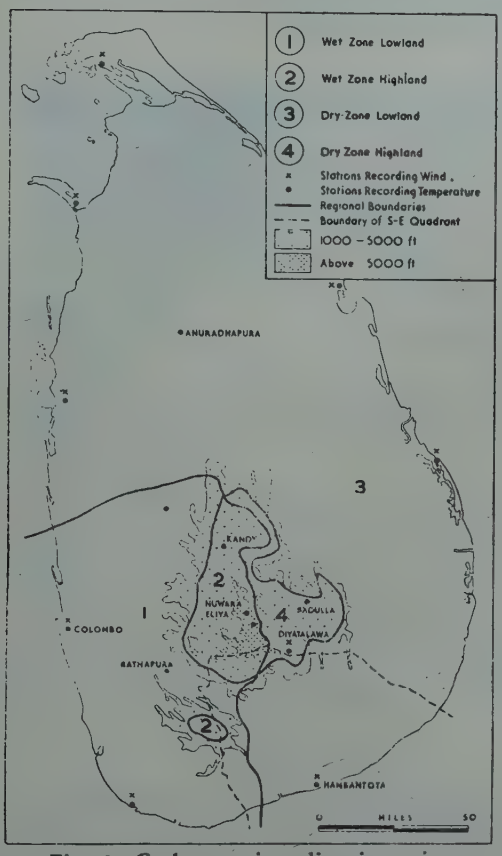

Fig. 2. Ceylon: major climatic regions.

(2) *Rainfall Regions*

Two broad rainfall regions, namely the 'wet' and the 'dry' zones, are recognized on the island. The 'dry' zone experiences long periods of drought during the period of the south-west monsoon. The boundary between the two rainfall zones is however conventionally based on the average annual distribution of rainfall, those parts of the island having over 75 in. of rain per year being held to form the 'wet' zone and the remaining parts the 'dry' zone (Fig. 1). Such isohyetal demarcation is of doubtful value and raises the problem of determining a more precise boundary between the two zones. This problem will be examined here only in so far as it is relevant to the study of the climate of the South-East Quadrant.

(3) *Climatic Regions*

The different regimes of temperature dependent on variations in relief and altitude have to be considered in association with the principal rainfall regions in attempting a division of the island into climatic regions. There are however only sixteen meteorological stations in the island which record temperature.[2] Of these eight are on the the coast at elevations under 100 ft., three at elevations between 100 ft. and 400 ft. and only five are in the highland area. An isotherm map based on the statistics from so few stations would obviously be of limited value. There is no simple relationship between temperature and altitude. Temperatures in general are lower

1. H. Jameson, 'The Batticaloa Kachan', *Journal of the Royal Meteorological Society*. vol. 67 (London, 1941), p. 55.

2. The location of these sixteen stations is shown on Fig. 2.

where the altitude is greater, but they also depend on local relief. Four broad climatic regions can nevertheless be recognized in the island (Fig. 2). These are listed below with average monthly and average annual statistics of rainfall and temperature at eight selected stations.

(a) "Wet" zone Lowland.

(i) Colombo (altitude: 20 ft.)

	J	F	M	A	M	J	J	A	S	O	N	D	Year
Rainfall (in.)	4·0	2·6	4·7	9·0	15·4	8·6	7·0	4·0	6·8	13·6	13·0	5·6	93·1
Temperature (°F)	79·2	79·7	81·0	81·9	82·2	81·4	80·9	80·8	81·0	79·9	79·4	79·0	80·5

(ii) Ratnapura (altitude: 130 ft.)

	J	F	M	A	M	J	J	A	S	O	N	D	Year
Rainfall (in.)	6·2	4·3	10·3	11·5	20·9	18·1	12·7	11·4	14·5	18·0	14·8	9·1	153·5
Temperature (°F)	80·2	81·4	82·2	82·4	81·8	80·7	80·6	80·4	80·4	80·0	80·0	79·8	80·8

(b) "Wet" zone Highland.

(i) Nuwara Eliya (altitude: 6,170 ft.)

	J	F	M	A	M	J	J	A	S	O	N	D	Year
Rainfall (in.)	6·9	2·0	4·0	5·0	8·4	10·4	10·9	7·5	8·2	9·7	9·2	7·8	90·4
Temperature (°F)	57·2	57·2	58·6	60·6	61·8	60·7	60·1	60·2	60·0	59·8	59·5	58·4	59·2

(ii) Kandy (altitude: 1,610 ft.)

	J	F	M	A	M	J	J	A	S	O	N	D	Year
Rainfall (in.)	6·3	2·3	5·8	6·5	7·5	8·7	7·3	5·6	6·4	10·5	11·0	8·4	86·9
Temperature (°F)	75·4	76·8	78·7	80·1	79·0	77·4	76·8	76·6	76·8	76·4	76·0	75·2	77·0

(c) "Dry" zone Lowland.

(i) Hambantota (altitude: 60 ft.)

	J	F	M	A	M	J	J	A	S	O	N	D	Year
Rainfall (in.)	3·9	1·4	3·3	3·8	4·1	2·0	2·0	1·4	2·8	4·8	7·5	5·6	43·2
Temperature (°F)	78·8	79·5	80·5	82·0	82·1	81·6	81·9	81·4	81·4	80·8	79·6	78·8	80·7

(ii) Anuradhapura (altitude: 300 ft.)

	J	F	M	A	M	J	J	A	S	O	N	D	Year
Rainfall (in.)	5·8	1·7	4·1	6·3	3·5	0·7	1·3	1·6	3·8	9·6	10·7	7·4	56·9
Temperature (°F)	76·3	78·3	81·4	83·0	83·4	83·1	83·4	83·4	83·4	81·2	78·6	76·6	81·0

(d) "Dry" zone Highland.

(i) Diyatalawa (altitude: 4,120 ft.)

	J	F	M	A	M	J	J	A	S	O	N	D	Year
Rainfall (in.)	6·6	2·4	4·8	6·5	6·1	1·9	2·0	3·0	4·4	9·2	10·4	8·0	65·5
Temperature (°F)	64·7	65·8	67·7	69·2	70·4	70·4	70·4	69·8	69·4	68·4	67·0	65·4	68·2

(ii) Badulla (altitude: 2,220 ft.)

	J	F	M	A	M	J	J	A	S	O	N	D	Year
Rainfall (in.)	10·3	3·1	5·0	6·9	4·7	1·5	2·1	3·1	4·4	8·9	10·2	11·2	71·9
Temperature (°F)	70·0	71·0	73·3	75·2	75·8	76·4	75·2	75·2	75·0	74·2	72·4	70·6	73·6

The boundary between the highland and lowland regions in both the 'wet' zone and the 'dry' zone cannot be indicated accurately on the basis of the figures from the few stations which record temperature. But an approximate boundary can be made out when one also takes into account significant changes in vegetation, in types of land use and the way of life of the local inhabitants. In the writer's

view the land between 1,000 ft. and 2,000 ft. is a transition zone between the lowland areas of obviously hot and oppressive temperature conditions and the upland areas of obviously cooler and less oppressive temperature conditions.[1] While the existence of the four climatic regions is beyond doubt, the linear boundaries shown on Fig. 2 must be regarded as provisional and only approximate.

THE SOUTH-EAST QUADRANT

The four climatic regions found in the island are represented in the South-East Quadrant (Fig. 2).[2]

The 'wet' zone types occur in a limited belt of country along the western and north-western parts of the area and the 'dry' zone types over the remainder

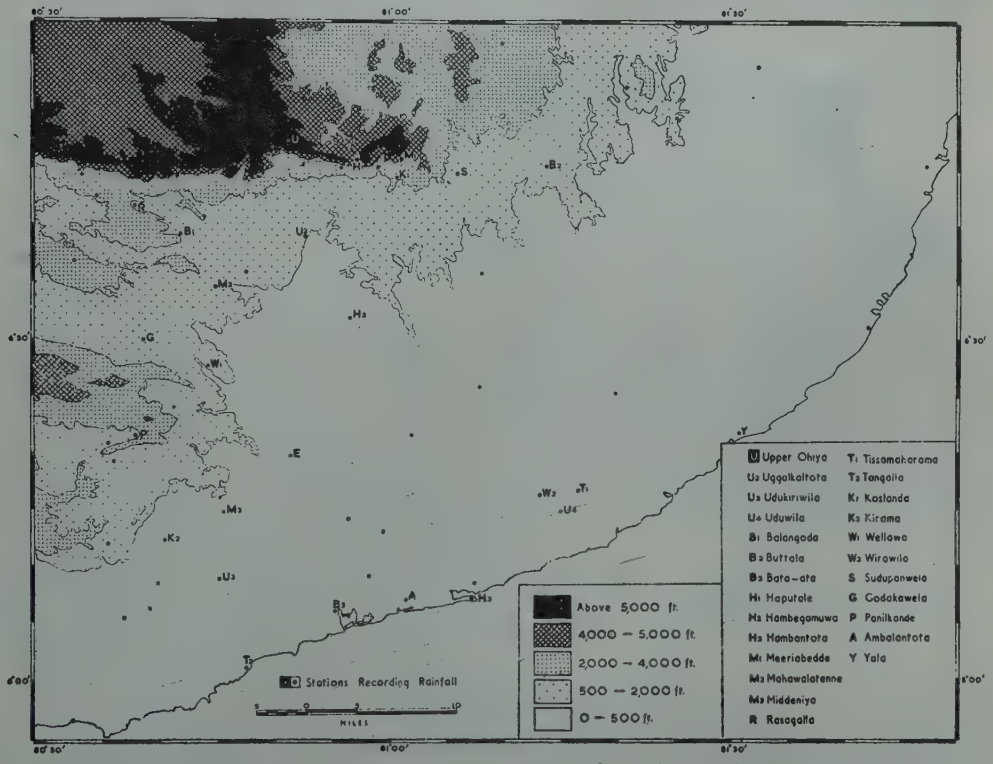

Fig. 3. South-east quadrant: relief and rainfall stations.

of the area. Though it is possible to identify and place these four climatic regions within the area by examining rainfall and temperature statistics and by field observations of types of land use and vegetation, the discerning of precise limits between the 'dry' and 'wet' zone remains an important problem.

1. Some writers have, on the basis of the Koeppen classification, placed the boundary at about the 4,500 ft. contour. This would, however, leave an all too extensive transition zone between the hot lowlands and the cooler uplands. See G. T. Thambyahpillay, 'Ceylon and the World Climatic Mosaic', *University of Ceylon Review*, vol. 12, no. 1 (1954), pp. 24-54.
2. The South-East Quadrant covers about 2,836 sq. miles of the island's total area of 25,332 sq. miles.

(1) Distribution of Rainfall

In constructing the map showing the distribution of average annual rainfall over the area (Fig. 4), the averages for the whole of the recorded period of sixty stations were examined (Figs. 3 and 4). Forty-four of these stations are located within the area and of these seven have continuous records for over 70 years, eight for periods from 50 to 70 years, eleven for 30 to 50 years, thirteen for 20 to 30 years and five for under 20 years. Among the sixteen stations outside the area, four have records for over 70 years, four for periods from 50 to 70 years, five for 20 to 30 years and three have very short records. Of the sixty stations, forty are in the upland tract and in the southern part of the lowland. In the remainder of the area there are few stations and this limitation is most evident in the central and eastern parts (Fig. 4).

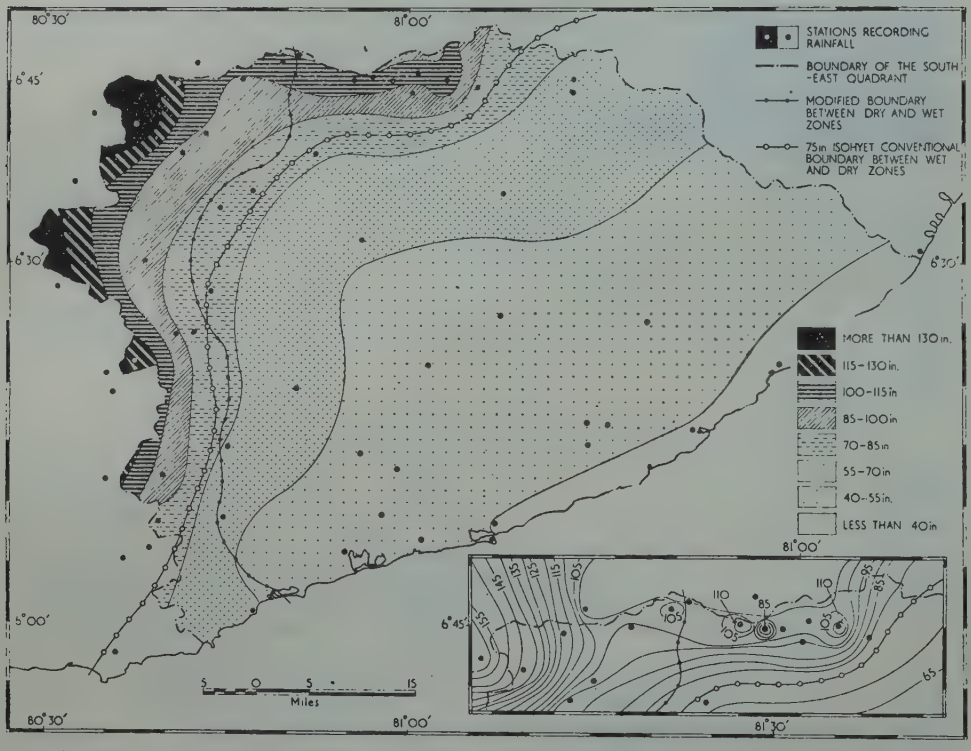

Fig. 4. South-east quadrant: average annual rainfall. Inset: detail of northern highland sector.

The accuracy of some of the rainfall records is open to question. Rainfall is recorded by officers of the Department of Meteorology at a small number of stations only, and at others by personnel at various government institutions, on plantations and in some cases even by rest-house keepers. The records made by officers of the Department of Meteorology can be considered reliable and the same applies to records from plantations and agricultural stations, where accurate recording of rainfall is of value to efficient crop production. On the other hand, there is evidence of inconsistent and inaccurate records especially at some hospitals, schools and rest-houses, where the recording of rainfall may become a playful pastime or may be considered an unnecessary call on one's time. In any event the degree of personal error is likely to be great at these latter stations.

Fig. 4 has obvious limitations, but it gives a reliable picture of the broad pattern of rainfall distribution. It reveals a considerable variation in the distribution of the average annual rainfall. The plateau and highland sections in the west and north receive relatively heavy rainfall, e.g., Kirama, 93·5 in; Panilkande, 128·0 in; Rasagalla, 144·8 in; Balangoda, 92·5 in; Meeriabedde, 103·6 in. and Koslanda, 94·9 in. Eastward of this crescent of heavy rainfall drier conditions prevail, e.g., Udukiriwila, 60·8 in; Middeniya, 65·5 in; Uggalkaltota, 72·0 in. and Sudupanwela, 76·5 in. To the south and east of these stations there is a further decrease in total rainfall and the coastal areas especially receive small amounts, e.g., Hambegamuwa, 55·8 in; Buttala, 66·1 in; Tangalla, 55·5 in; Hambantota, 43·2 in. and Yala, 36·2 in.

Further significant observations on the distribution of rainfall can be made on considering the average monthly figures for some selected stations, together with the relief and rainfall maps (Figs. 3 and 4). There is a wide variation in the distribution of rainfall at each station from month to month, as well as in the figures for a selected month between one station and another. These variations are due primarily to the location of each station in relation to the seasonal wind systems.

The maximum rainfall at nearly all stations occurs during the period of the north-east monsoon, indicating that the rains during this period are widespread in contrast to the rainfall during the period of the south-west monsoon which is more restricted to the western and north-western sectors of the area. The following average figures for May, the month of maximum rainfall during the south-west monsoon, at three selected stations placed from west to east within a distance of only fifteen miles illustrates this point:[1] Kirama (alt: 260 ft.), 9·1 in; Middeniya (alt: 400 ft.), 5·2 in. and Embilipitiya (alt: 250 ft.), 4·5 in. In November, which is generally the month of maximum rainfall during the period of the north-east monsoon, these same stations have the following figures:—Kirama, 12·4 in; Middeniya, 12·0 in; Embilipitiya, 9·9 in. There is a better annual distribution of rainfall in the western parts of the area as these parts receive rain from both monsoons, while the remaining parts which receive rain mostly during the period of the north-east monsoon experience relatively dry conditions of varying duration between the months of May and September.

There is also an important but variable control exercised by relief and altitude on the distribution of both seasonal and annual rainfall, as shown by the following analysis of data relating to four selected upland stations placed from west to east.

STATION	ALTITUDE (FT.)	MAY AVERAGE (IN.)	NOVEMBER AVERAGE (IN.)	ANNUAL AVERAGE (IN.)
RASAGALLA	1,750	16·5	14·9	144·8
UPPER OHIYA	6,000	7·1	17·2	97·8
HAPUTALE	4,880	6·0	13·9	85·7
MEERIABEDDE	3,600	7·8	18·5	103·6

Rasagalla, though at a comparatively low elevation, receives the highest annual rainfall as it is more favourably placed in relation to the wind circulations of both monsoon periods. Upper Ohiya, located at a higher elevation, however, gets only

1. These three stations were selected in preference to others in order to neutralize as far as possible the influence of high altitude and strong relief on rainfall. Coastal stations were not selected as monthly variations in rainfall, especially in November, are comparatively negligible.

97·8 in. per year compared to 144·8 in. at Rasagalla, and moreover despite its location slightly leeward of the winds during the period of the north-east monsoon, receives 17·2 in. in November and only 7·1 in. in May. The low figure for May at Upper Ohiya is a sharp contrast to the 16·5 in. received at Rasagalla. This is related primarily to the fact that the strong winds of the south-west monsoon deposit much of their moisture at intermediate levels, the winds being relatively dry when elevations of over 5,000 ft. are reached. During the period of the north-east monsoon, however, rainfall is carried over the mountain divide to both these stations. Haputale, despite its location in a gap, has the lowest total of the four stations. This station is less open to the influences of the south-west winds and furthermore the freer movement of air through the gap results, as is often experienced, in drizzle and light fog rather than in heavy orographic rain. Meeriabedde, the easternmost of the four stations gets a total rainfall of 103·6 in., which is more than the rainfall at Upper Ohiya or Haputale but less than at Rasagalla. Of the four stations, it is the one that is most suitably located in relation to the winds during the period of the north-east monsoon, and which receives the highest rainfall for November, namely 18·5 in. Though it is further removed from the direct influence of the south-west winds, it nevertheless gets more rain in May than either Upper Ohiya or Haputale, on account of its not too high elevation and its location at the head of a valley facing the south-west.

An analysis of the following data for four coastal stations placed from west to east, provides more observations of interest.

STATION	ALTITUDE (FT.)	MAY AVERAGE (IN.)	NOVEMBER AVERAGE (IN.)	ANNUAL AVERAGE (IN.)
TANGALLA	20	7·4	7·5	55·5
AMBALANTOTA	20	4·6	7·4	44·4
HAMBANTOTA	60	4·1	7·5	43·2
YALA	10	2·2	6·8	36·2

The total rainfall is in all cases lower than in other parts of the area and decreases from west to east. The totals for all four stations are low because little orographic rain results on account of the low elevation, and more particularly so as wind directions in this area are generally parallel to the coast, especially during the period of the north-east monsoon. This is evident from the almost uniform figures for November at each of the four stations which are so placed that they cover nearly the full length of the coast. During the period of the south-west monsoon, the winds are more effective in bringing rain to the west, and the amount of rain increases from east to west.

Another feature, as shown by the following data, is that the amount of convectional rain is low in the coastal areas and that there is a progressive increase in this type of rain landward. In illustrating this point the figures for March and April, one of the two periods during which convectional rain is dominant, have been selected in preference to the figures for October and September as the convectional rain is supplemented to a greater degree by cyclonic rain in the latter period.

STATION	ALTITUDE (FT.)	MARCH AVERAGE (IN.)	APRIL AVERAGE (IN.)
AMBALANTOTA	20	3·4	3·8
EMBILIPITIYA	250	6·7	6·9
HAMBEGAMUWA	500	8·3	7·4
UPPER OHIYA	6,000	9·2	11·3

This increase in the rainfall from coast to interior can be associated with the fact that the central area of the island is the focus of convectional activity.

One other observation is that the rainfall in February is uniformly low at nearly all stations. This observation is true for stations in every part of the island. One possible explanation is that in February, which is a month of little cloud and a weak north-east wind, the upper air currents are very dry, thereby retarding the possible condensation of moisture contained in the local convectional wind circulations.[1]

(2) Variability of Rainfall

Throughout the area the rainfall is highly variable. The total and seasonal rainfall vary considerably from year to year at each station. This high variability applies both to stations showing marked seasonal variation in the distribution of average rainfall through the year and to those that have a relatively even distribution of average rainfall. It also applies to stations having relatively low amounts of monthly and annual average rainfall as well as to stations with correspondingly high amounts. In an attempt to assess the variable nature of the rainfall more fully, the annual and monthly figures for both rainfall and the number of 'wet' days over a twenty-five year period (1926-1950) at six selected stations were analysed with the aid of scatter diagrams.[2] The number of 'wet' days were considered in this analysis because it is an important consideration in assessing the effectiveness of rainfall. A large amount of rain limited to a few days in each month is obviously less effective than, for example, a moderate amount of rain with a better distribution. This fact is of special importance in areas of high rates of evaporation and of run-off. However, the results obtained by a consideration of the number 'wet' days, though of some significance, are inconclusive for the following reasons. A 'wet' day is defined as one with 0·01 in. or more of rain. A rainfall of only 0·01 in. is hardly of any consequence in Ceylon, for it is of little benefit to either plant, animal or human life under the prevailing conditions of high temperatures and high rates of evaporation. As such the actual number of effective 'wet' days is in reality less than the number recorded. The relatively great number of 'wet' days recorded also tends to mask the fact that much of the rain occurs in short and torrential showers. For example in August 1941, the rainfall at Rasagalla for three consecutive days totalled 76 in.

The principal results obtained from the above analysis of the rainfall at the six selected stations for the period 1926-1950, are set out in the following sections (Tables 1-6). It must be pointed out that in assessing the period of drought at each station the month of February has not been included for the following reasons. February is generally a month of low rainfall at all stations with the exception of some in the ultra-wet zone. Reference to the data in Tables 1-6 will show that the relatively dry conditions in February are preceded by periods of higher rainfall from November to January and followed by higher rainfall in March and April. It was, therefore, considered erroneous to include this month in assessing a period of continued drought.

1. A. J. Bamford, 'Notes on the Climate of Western Ceylon with Special Reference to Upper Winds', *Ceylon Journal of Science*, vol. 1, part 3 (1924), p. 194.
2. The statistical data relating to 'wet' days are only available in the manuscript records of the Colombo Observatory.

TABLE 1: DISTRIBUTION OF RAINFALL AND WET DAYS FOR THE PERIOD 1926 - 1950

AT RASAGALLA (ALTITUDE 1,750 FT.)

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
Average Rainfall (in.)	8·0	5·8	12·0	11·4	16·5	16·1	12·1	9·0	11·5	15·5	14·9	11·6	144·8
Median Rainfall (in.)	7·5	5·5	12·0	13·0	16·0	14·9	9·8	7·9	8·9	15·5	13·5	11·3	140·0
Rainfall Variability (in.) Absolute Max. -	14·6	15·3	19·0	22·8	81·3	37·7	18·7	30·2	23·0	27·0	29·3	30·1	195·6
Absolute Min. -	0·2	0·8	4·3	4·2	2·2	6·0	3·0	1·7	2·2	4·9	7·7	4·0	111·5
Number of Years with Monthly Rainfall over 4 in.	19	17	25	25	21	25	24	23	23	25	25	24	
Number of Years with Monthly Rainfall from 2·1 - 4 in.	4	6	0	0	4	0	1	1	2	0	0	1	
Number of Years with Monthly Rainfall from 1 - 2 in.	1	1	0	0	0	0	0	1	0	0	0	0	
Number of Years with Monthly Rainfall under 1 in.	1	1	0	0	0	0	0	0	0	0	0	0	
Number of Years with no Monthly Rainfall	0	0	0	0	0	0	0	0	0	0	0	0	
Number of Years with Annual Rainfall over 75 in.													25
Number of Years with Annual Rainfall under 75 in.													0
Median of Wet Days	14	13	18	19	18	22	19	18	17	20	22	18	223
Absolute Variability of Wet Days Max. -	25	22	23	28	29	28	25	28	23	30	28	25	247
Min. -	4	4	6	9	6	17	7	9	7	12	10	10	166
Number of Years with over 10 Wet Days per Month	19	15	24	24	23	25	24	23	23	25	24	24	
Number of Years with 5-10 Wet Days per Month	5	8	1	1	1	0	1	2	2	0	1	1	
Number of Years with under 5 Wet Days per Month	1	2	0	0	1	0	0	0	0	0	0	0	
Number of Years with no Wet Days per Month	0	0	0	0	0	0	0	0	0	0	0	0	

There is very little probability of a dry period, a monthly rainfall of under 2 in. being recorded in only five instances. All months have medians of over 5 in. of rain and over 10 wet days, with 10 months having over 15 wet days. The rainfall is nevertheless highly variable, but it is at all times more than adequate for purposes of local agriculture which includes the cultivation of tea, padi and vegetables. In fact, in certain periods the excessive rainfall results in much damage to crops and also in floods. This station is characteristic of the 'wet' zone highlands in that there is little probability of a dry period.

TABLE 2: DISTRIBUTION OF RAINFALL AND WET DAYS FOR THE PERIOD 1926 - 1950

AT UPPER OHIYA (ALTITUDE 6,000 FT.)

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
Average Rainfall (in.)	10·3	4·2	9·2	11·3	7·1	1·8	2·2	2·8	4·9	13·0	17·2	13·3	97·8
Median Rainfall (in.)	7·7	5·2	7·6	11·6	6·7	1·4	1·3	2·2	3·7	10·1	15·6	11·6	89·0
Rainfall Variability (in.) Absolute Max. -	23·9	17·5	18·5	32·3	21·1	4·2	5·8	11·1	15·2	24·9	28·8	22·4	143·6
Absolute Min. -	1·0	0·5	2·8	3·2	1·2	0·0	0·0	0·1	0·2	3·5	3·6	3·7	55·5
Number of Years with Monthly Rainfall over 4 in.	20	16	21	23	20	1	3	7	8	24	24	23	
Number of Years with Monthly Rainfall from 2·1-4 in.	2	4	4	2	3	7	4	9	8	1	1	2	
Number of Years with Monthly Rainfall from 1 - 2 in.	3	4	0	0	2	8	9	4	3	0	0	0	
Number of Years with Monthly Rainfall under 1 in.	0	1	0	0	0	9	8	5	6	0	0	0	
Number of Years with no Monthly Rainfall	0	0	0	0	0	0	1	0	0	0	0	0	
Number of Years with Annual Rainfall over 75 in.													23
Number of Years with Annual Rainfall under 75 in.													2
Median of Wet Days	18	12	14	19	18	9	7	8	11	20	24	21	177
Absolute Variability of Wet Days Max. -	28	20	27	26	30	23	20	20	23	28	30	30	227
Min. -	6	3	5	10	4	3	0	2	2	12	13	7	140
Number of Years with over 10 Wet Days per Month	22	16	21	24	20	10	9	9	13	25	25	24	
Number of Years with 5-10 Wet Days per Month	3	6	4	1	4	12	7	9	8	0	0	1	
Number of Years with under 5 Wet Days per Month	0	3	0	0	1	3	8	7	4	0	0	0	
Number of Years with no Wet Days per Month	0	0	0	0	0	0	1	0	0	0	0	0	

There is a high probability of a marked dry period of three to four months, in which three months have medians of under 3 in. and one under 4 in. No month, however, has a median of under 5 wet days. There is a much greater tendency towards more frequent periods of low rainfall when compared with Rasagalla, but this has little adverse effect on local agriculture especially the cultivation of tea which is the principal crop. On the basis of either the annual median or the annual average rainfall, both of which are over 75 in., this station can be placed in the 'wet' zone highlands. The monthly regime is, however, more characteristic of the 'dry' zone highlands in that there is a distinct probability of dry periods.

TABLE 3: DISTRIBUTION OF RAINFALL AND WET DAYS FOR THE PERIOD 1926 - 1950

AT GODAKAWELA (ALTITUDE 670 FT.)

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
Average Rainfall (in.)	5·5	3·1	8·3	8·9	7·7	6·5	5·4	4·0	5·6	9·8	12·3	8·7	86·4
Median Rainfall (in.)	4·7	2·7	8·1	8·6	4·6	6·0	4·2	3·3	5·3	10·0	11·6	8·0	84·0
Rainfall Variability (in.) Absolute Max. -	12·0	5·9	13·3	18·3	30·3	11·5	11·4	13·3	12·7	18·2	19·2	15·9	103·0
Absolute Min. -	0·1	0·2	0·9	5·3	0·4	2·1	0·7	1·0	2·4	2·8	3·6	2·8	62·0
Number of Years with Monthly Rainfall over 4 in.	14	7	22	25	13	19	13	10	16	22	23	22	
Number of Years with Monthly Rainfall from 2·1 - 4 in.	6	8	1	0	7	6	10	8	9	3	2	3	
Number of Years with Monthly Rainfall from 1 - 2 in.	1	5	1	0	3	0	1	7	0	0	0	0	
Number of Years with Monthly Rainfall under 1 in.	4	5	1	0	2	0	1	0	0	0	0	0	
Number of Years with no Monthly Rainfall	0	0	0	0	0	0	0	0	0	0	0	0	
Number of Years with Annual Rainfall over 75 in.													17
Number of Years with Annual Rainfall under 75 in.													8
Median of Wet Days	9	9	13	16	12	20	18	17	16	18	20	15	178
Absolute Variability of Wet Days Max. -	20	13	21	25	28	30	30	29	23	30	27	22	228
Min. -	1	1	3	8	5	14	11	10	6	10	9	8	146
Number of Years with over 10 Wet Days per Month	10	9	21	22	15	21	23	23	22	23	23	20	
Number of Years with 5-10 Wet Days per Month	9	11	3	3	10	4	2	2	3	2	1	5	
Number of Years with under 5 Wet Days per Month	6	5	1	0	0	0	0	0	0	0	0	0	
Number of Years with no Wet Days per Month	0	0	0	0	0	0	0	0	0	0	0	0	

The medians indicate a relatively even distribution of rainfall and no month has a median of under nine wet days. Though variable, the amount of rain in all months is rarely inadequate for purposes of local agriculture which include the cultivation of padi, coconuts, tobacco and vegetables. A period of drier conditions can be expected in July and August which have medians of 4·2 in. and 3·3 in. respectively. Rainfall conditions are generally characteristic of the 'wet' zone lowlands. In certain years, however, the occurrence of dry periods makes the rainfall distribution more typical of the 'dry' zone lowlands. The changing regimes at this station are indicative of circumstances that often lead to an over expansion of agriculture and to sudden crop failures.

TABLE 4: DISTRIBUTION OF RAINFALL AND WET DAYS FOR THE PERIOD 1926 - 1950

AT UDUKIRIWILA (ALTITUDE 160 FT.)

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
Average Rainfall (in.)	4·0	2·4	5·9	5·6	6·7	3·8	3·0	2·3	3·9	6·1	9·3	7·3	60·8
Median Rainfall (in.)	3·5	2·2	5·1	5·7	8·2	3·4	1·6	2·5	2·7	6·6	9·4	6·6	59·0
Rainfall Variability (in.) Absolute Max. -	9·0	8·5	13·9	11·9	24·7	10·9	7·5	7·1	7·9	12·2	16·6	13·5	89·3
Absolute Min. -	0·1	0·0	0·3	1·6	0·2	0·7	0·3	0·3	0·6	1·4	1·3	1·1	43·9
Number of Years with Monthly Rainfall over 4 in.	9	7	17	19	18	11	4	6	7	18	21	20	
Number of Years with Monthly Rainfall from 2·1-4 in.	8	8	5	5	4	9	6	10	10	4	3	4	
Number of Years with Monthly Rainfall from 1-2 in.	2	6	1	1	0	4	7	7	7	3	1	1	
Number of Years with Monthly Rainfall under 1 in.	6	3	2	0	3	1	8	2	1	0	0	0	
Number of Years with no Monthly Rainfall	0	1	0	0	0	0	0	0	0	0	0	0	
Number of Years with Annual Rainfall over 75 in.													4
Number of Years with Annual Rainfall under 75 in.													21
Median of Wet Days	8	6	9	12	13	15	11	11	12	13	16	13	140
Absolute Variability of Wet Days Max. -	20	19	18	19	28	23	20	25	16	20	26	20	170
Min. -	1	0	3	5	4	3	4	4	3	4	7	4	107
Number of Years with over 10 Wet Days per Month	8	3	11	13	14	24	13	14	15	20	22	17	
Number of Years with 5-10 Wet Days per Month	10	15	12	12	10	0	10	8	8	4	3	7	
Number of Years with under 5 Wet Days per Month	7	6	2	0	1	1	2	3	2	1	0	1	
Number of Years with no Wet Days per Month	0	1	0	0	0	0	0	0	0	0	0	0	

A definite dry period can be expected from June to September. The rainfall during these months seldom exceeds 5 in. and three months have medians under 3 in. No month, however, has a median of under 5 wet days. The amount of rainfall and the number of wet days are usually lower than at Godakawela, with the regimes being more frequently characteristic of the 'dry' zone lowlands than the 'wet' zone. Rainfall conditions during favourable years may permit the cultivation of a wide variety of crops including padi, citronella, coconut and vegetables. Sources of supplementary water supply, especially for domestic use and livestock, are however essential if widespread disaster is to be avoided during dry years.

TABLE 5: DISTRIBUTION OF RAINFALL AND WET DAYS FOR THE PERIOR 1926 - 1950

AT BUTTALA (ALTITUDE 510 FT.)

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
Average Rainfall (in.)	9·9	2·9	6·3	8·4	3·7	0·7	1·8	2·3	3·6	9·1	12·8	8·2	66·1
Median Rainfall (in.)	3·3	2·6	6·0	8·1	2·7	0·2	0·9	1·9	2·9	8·3	11·5	7·6	66·0
Rainfall Variability (in.) Absolute Max. =	20·2	12·2	18·1	18·3	11·8	3·7	7·4	7·7	8·3	16·2	24·2	21·1	92·1
Absolute Min. =	0·0	0·3	1·1	1·9	0·4	0·0	0·0	0·0	0·0	2·0	2·6	0·8	46·6
Number of Years with Monthly Rainfall over 4 in.	10	5	19	22	10	0	2	3	9	22	24	19	
Number of Years with Monthly Rainfall from 2·1-4 in.	7	9	3	2	9	2	7	9	8	3	1	3	
Number of Years with Monthly Rainfall from 1-2 in.	2	6	3	1	3	3	4	5	5	0	0	2	
Number of Years with Monthly Rainfall under 1 in.	5	5	0	0	3	12	8	4	2	0	0	1	
Number of Years with no Monthly Rainfall	1	0	0	0	0	8	4	4	1	0	0	0	
Number of Years with Annual Rainfall over 75 in.													5
Number of Years with Annual Rainfall under 75 in.													20
Median of Wet Days	7	4	9	11	6	1	2	4	5	14	16	10	94
Absolute Variability of Wet Days Max. =	20	14	21	26	17	5	8	8	13	22	26	18	115
Min. =	0	1	3	4	1	0	0	0	0	4	6	2	64
Number of Years with over 10 Wet Days per Month	7	1	8	16	4	0	0	0	1	18	23	10	
Number of Years with 5-10 Wet Days per Month	10	11	13	8	12	1	6	11	15	6	2	13	
Number of Years with under 5 Wet Days per Month	7	13	4	1	9	16	15	10	8	1	0	2	
Number of Years with no Wet Days per Month	1	0	0	0	0	8	4	4	1	0	0	0	

There is a definite dry period from May to September in which five months have medians of under 3 in. and of these two have under one inch. June is totally dry in eight of the twenty-five years, July and August in four years. The number of wet days for June does not exceed one in sixteen of the twenty-five years and in July does not exceed two in fourteen years. The rainfall is generally inadequate at all seasons and far too variable even during the rainy periods for permanent cultivation of unirrigated crops throughout the year under present practices. It is doubtful whether dry farming will by itself be successful in this area. Today, permanent agricultural settlement in this 'dry' zone lowland area is limited to the few irrigated padi tracts.

TABLE 6: DISTRIBUTION OF RAINFALL AND WET DAYS FOR THE PERIOD 1926 - 1950

AT TISSAMAHARAMA (ALTITUDE 80 FT.)

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
Average Rainfall (in.)	4·4	1·4	3·6	3·9	3·2	0·7	0·9	0·8	2·0	4·9	8·7	6·4	41·6
Median Rainfall (in.)	4·9	1·7	3·3	4·0	2·6	0·9	0·3	0·3	0·9	5·4	9·8	5·2	44·0
Rainfall Variability (in.) Absolute Max. -	14·4	7·8	9·8	9·3	10·9	5·2	6·7	3·5	8·0	11·5	19·0	14·2	58·3
Absolute Min. -	0·0	0·0	0·3	1·7	0·0	0·0	0·0	0·0	0·0	1·3	1·6	1·1	26·1
Number of Years with Monthly Rainfall over 4 in.	13	1	10	12	8	1	1	0	5	17	22	15	
Number of Years with Monthly Rainfall from 2·1-4 in.	1	8	8	11	6	2	3	4	4	4	1	6	
Number of Years with Monthly Rainfall from 1-2 in.	5	10	4	2	6	8	2	6	3	4	2	4	
Number of Years with Monthly Rainfall under 1 in.	4	4	3	0	3	12	16	9	11	0	0	0	
Number of Years with no Monthly Rainfall	2	2	0	0	2	2	3	6	2	0	0	0	
Number of Years with Annual Rainfall over 75 in.													0
Number of Years with Annual Rainfall under 75 in.													25
Median of Wet Days	7	4	8	9	7	4	2	2	4	10	15	11	82
Absolute Variability of Wet Days Max. -	20	14	15	15	21	14	11	9	12	15	22	18	112
Min. -	0	0	2	5	0	0	0	0	0	4	5	3	66
Number of Years with over 10 Wet Days per Month	6	1	3	5	5	2	1	0	1	11	21	14	
Number of Years with 5-10 Wet Days per Month	13	8	17	20	12	8	2	4	8	12	4	10	
Number of Years with under 5 Wet Days per Month	4	14	5	0	6	13	19	15	14	2	0	1	
Number of Years with no Wet Days per Month	2	2	0	0	2	2	3	6	2	0	0	0	

There is a very high probability of a dry period from May to September. The median for May is 2·6 in., for June 0·9 in., for July 0·3 in., for August 0·3 in., and for September 0·9 in. August is totally dry in six of the twenty-five years, and May, June, July and September in two of the twenty-five years. The number of wet days for July does not exceed one in eleven of the twenty-five years, for August in thirteen years. Today, this area is one of the most intensively settled parts of the 'dry' zone lowlands, but permanent settlement and the successful cultivation of crops, especially padi and also cotton, is dependent entirely on satisfactory supplies of water from large irrigation tanks. In this area of scanty rainfall and strong winds, the bad management of farm lands often results in the formation of an arid landscape.

(3) The Boundary between the "Wet" and "Dry" zones

From some of the observations made in the above analysis of rainfall variability it is clear that the use of 75 in. annual isohyet as an indication of the boundary separating the 'wet' zone from the 'dry' zone, as shown on Fig. 4, is questionable. For example, the average or median annual rainfall at Godakawela (Table 3) is greater than 75 in., but annual rainfall was under that figure in eight of the twenty five years reviewed. At Upper Ohiya (Table 2) the annual average is 97·8 in. and the median 89·0 in., but at this station the rainfall regime in more characteristic of the 'dry' zone, in that it has a dry period of from three to four months.[1] An annual average rainfall of less than 75 in. is certainly not indicative of dry conditions, and when used by itself without qualification is of little practical value. An average figure does not correctly describe true climatic conditions within an area as it masks the different totals and the regimes of rainfall experienced from year to year, especially in areas where the variability is high. For example, though the annual average rainfall and the annual median at Udukiriwila (Table 4) are lower than at Buttala (Table 5), the regimes at the former station are usually less characteristic of the 'dry' zone than the regimes at the latter. The criterion of value that has to be considered in an attempt to place the boundary between the 'wet' and 'dry' zones is not the annual rainfall but the regime of rainfall with special reference to the possible occurrence of periods of effective drought.

These considerations lead to two related and important problems, namely, those of discerning the factor of 'effective rainfall' and of defining a period of drought in terms of this factor. Little work on this subject has been done in Ceylon, nor are the data available sufficient for the purpose. As pointed out earlier the available data on temperatures are of little value for detailed work. Furthermore, there are only nine stations in the island that record wind velocities (Fig. 2). Of these eight are located around the coast and one in the central highlands. Hambantota on the coast is the only station within the South-East Quadrant. The rate of evaporation depends to a large extent on temperatures and winds, and the data relating to these two are necessary in determining 'effective rainfall'.

In spite of these difficulties a paper on effective rainfall in Ceylon has been published by P. G. Cooray.[2] Two fundamental weaknesses are evident in this paper. First, in the application of the formula used to determine precipitation/evaporation ratios, saturation deficit figures were available for only sixteen of the thirty-eight stations plotted, and the figures for twenty-two stations have been interpolated. Second, an average wind velocity has been used in all calculations. Wind velocities vary considerably from place to place and also from season to season at any one place. For these and other reasons unfortunately much of the value of this pioneer effort has been lost and one cannot place complete reliance on Cooray's contention that the monthly 'effective rainfall' required is between one and two inches.

It is obviously not possible to construct a reliable map showing the distribution of 'effective rainfall' as the statistical material available is inadequate. Rates of evaporation vary considerably in different sectors of the island, from place to place within each sector and from season to season at any one place. Soil moisture depends on a number of interrelated factors which include rainfall,

1. This is true of nearly all stations in the highland area east of Upper Ohiya.
2. P. G. Cooray, 'Effective Rainfall and Moisture Zones in Ceylon', *Bull. of the Ceylon Geog. Soc.*, vol. 3, no. 2 (1948), pp. 39-42.

temperature, winds, slope, soils and vegetation cover. For instance, within a five-year period the rainfall recorded at Uduwila showed significant variations from the rainfall recorded at Wirawila (Fig. 3). These two stations are only about three miles apart; both are near the coast and similarly located on flat ground, but around the latter station the forest has progressively been cleared over about 900 acres and there is also much bare ground. The figures are as follows (in inches):

	UDUWILA	WIRAWILA
1946	40·90	41·18
1947	44·88	46·36
1948	42·88	39·91
1949	43·23	39·69
1950	37·39	27·86

It is quite probable that these differences in rainfall between the two stations in a given year can be accounted for in terms of the varying number of thunderstorms at each station. But there is also the distinct possibility that the amounts of rainfall, which are usually measured at 07.30 and 17.30 hours L.T. at each station, vary not because of a difference in the rainfall but as a result of different rates of evaporation in each rain-gauge.

In order to determine the amount of rainfall that is required for crop and plant growth, the geographer has, in the absence of reliable criteria for estimating 'effective rainfall', to rely on careful study of rainfall statistics, correlated with observations of types of land use and agricultural practices, and on interrogation in the field. Using an appraisal based on these lines, Miss E. K. Cook suggested that 4 in. was the monthly rainfall that would permit the growing of crops.[1] Even if 4 in. per month be taken as a criterion, there remains the problem of relating a monthly figure to periods of effective drought. Here again one is hampered by having no uniformly applicable and measurable criterion. An estimate of what constitutes a period of effective drought is relative to and varies with the characteristics of each plant or its associations: some plant associations will survive longer than others during periods of drought. In the absence of such criteria to determine a period of effective drought the geographer is compelled again to rely on an alternative method, namely, to undertake a careful reconnaisance of the topography in an attempt to observe and record phenomena which can be taken to indicate an adaptation of agricultural settlement to an environment which is conditioned by the occurrence of periods of effective drought. In Ceylon, the practice of *chena* cultivation is without doubt one such form of adaptation. The term *chena* is a local name for shifting cultivation. It is applied as an adjective to the practice of shifting cultivation and as a noun to forest clearings both cultivated and abandoned. It is the traditional form of adjustment of settlement and agricultural practices by the peasant to a rainfall regime which has a definite period of effective drought. Experience has taught him that continuous subsistence cropping of the land throughout the year is not possible under these conditions without irrigation. Consequently, the sight of a *chena* on the land can be taken to indicate the occurrence of periods of effective drought and it therefore can also be considered an indicator of the transition from the 'wet' to the 'dry' zone.

The above method of investigation is, however, not without certain limitations and difficulties. For example, characteristics usually associated with *chena* clearings in the 'dry' zone sometimes appear to occur in clearings in parts

1. E. K. Cook, *A Geography of Ceylon* (Madras, 1951), p. 117.

of the island which have no recognizable periods of drought. This is especially true of certain upland tracts where there is acute land hunger. These patches of cultivation are usually looked upon by the peasants as permanent homesteads and it is possible for a trained observer with a sound knowledge of local conditions to distinguish between these two apparently similar types of settlement. Again, the change from permanent unirrigated subsistence cropping of the land to *chena* cultivation may be masked in certain areas by plantations. Crops like tea and rubber can be grown in areas with seasonal dry periods if the total rainfall and elevation is suitable. This is especially true of areas south and east of Koslanda. It is also possible that permanent subsistence cropping may be observed in the 'dry' zone on lands not directly irrigated but where there is a local increase in soil moisture on account of the proximity of perennial water courses or irrigation works.

In the South-East Quadrant, typical changes in land use and types of settlement indicative of the tranisition from the 'wet' to the 'dry' zone, as exemplified by *chena* cultivation, were observed at places through a belt extending from between Tangalla and Bata-ata through Udukiriwila, Middeniya, Wellawa, Mahawalatenne and Uggalkaltota to the area south of Upper Ohiya (Fig. 3).[1] An examination of the monthly averages and medians of rainfall at stations located at or nearest these places eg: Bata-ata, Udukiriwila, Middeniya, Wellawa, Mahawalatenne and Uggalkaltota shows that these stations have three or more consecutive months in each of which the rainfall is below 4 in. It is maintained that a more realistic limit to the 'dry' zone is indicated by a line bounding the area which has on the average three or more consecutive months in each of which the rainfall is below 4 in.

The boundary suggested on this basis is shown on Fig. 4, and differs from the boundary shown by the 75-in. annual isohyet, especially in the south-western and northern parts of the South-East Quadrant. In the south-west a larger area is included as 'wet' zone and in the northern part the extent of the 'dry' zone is considerably increased. The boundary has obvious limitations and cannot be placed more accurately because of the small number of stations within the zone of transition. Even if there were a greater number of stations the linear boundary drawn would only indicate a zone of transition.

In conclusion it is of value to draw attention to some important influences of climate on land use and settlement. The continuous cultivation of crops throughout the year without irrigation is not possible in a greater part of the South-East Quadrant, on account of the long periods of drought. The high variability of the rainfall imposes further limitations on agriculture and widespread disaster is sometimes experienced, even in the 'wet' zone, on account of the total or seasonal failure of the rains. On the other hand floods may occur, particularly in the 'wet' zone during periods of heavy rainfall and much damage to crops and property may result. The supply of water for domestic purposes is always a problem especially in the 'dry' zone and the position becomes acute in areas in which the streams run dry. In these areas supplementary sources of water suply are essential if the land is to be permanently settled.

1. These observations were made both from the ground and from a light aeroplane.

RICE PRODUCTION IN SIERRA LEONE

By H. R. JARRETT

The writer wishes to record his thanks to Mr. D. Calcott, Lecturer in Rural Science, Fourah Bay College, who has read the manuscript and made valuable suggestions.

"For the third year in succession, rice shipments are being determined by the decisions of importers rather than by quantities protentially available for export."[1] These words underlined the changing world situation with regard to rice, and threw into relief the anxieties of traditional rice-exporting countries as world exports dropped by 12% in four years, from 5,000,000 metric tons in 1951 to 4,400,000 in 1954. It was this situation which loomed large in the minds of delegates to the Third Special Meeting on the Economic Aspects of the Rice Industry, held in Bangkok, September-October, 1955, and its gravity was admitted by all rice exporters.

One reason, at least, for this state of affairs is not difficult to find. A recent article[2] emphasizes the undesirable nature of a situation in which Malaya needs to import more than 50% of its rice needs, and indicates how serious this deficiency was during the Korean crisis, going on to point the obvious moral that it is imperative to narrow the gap between food production and requirements. When a large number of consumer countries, all actuated by fears of recurrent world "crises", thinks thus, it is not difficult to see why overall exports are slackening. It is the neo-mercantilism of contemporary economic thought in operation.

West Africa as a whole has never been a major rice producer, and has traditionally imported a large share of its modest needs. This is particularly true of Nigeria, where the value of the annual rice crop is only one-tenth of that of cassava and also one-tenth of that of the Gold Coast;[3] Sierra Leone and the Gambia depend to a greater extent upon rice. The following table will help to put the matter in perspective.[4]

TABLE 1: RICE PRODUCTION IN WEST AFRICA AND MALAYA

	Gambia	Sierra Leone	Gold Coast	Nigeria	Malaya
AREA UNDER RICE (ACRES)	60,000	780,000	50,000	165,000	900,000
ANNUAL PRODUCTION (TONS)	20,000	270,000	22,000	50,000	690,000
IMPORTS (TONS)	2,600 (1953)	819 (1954)	815 (1949)	NOT AVAILABLE BUT VERY LITTLE	67,000

1. *Monthly Bulletin of Agricultural Economics and Statistics* (Rome; Sept., 1955), p. 13.
2. J. R. Johnstone, "Observations on Agricultural Development in Malaya", *Tropical Agriculture* (London, 1955), pp. 274-7.
3. Figures cited in F. J. Pedler, *Economic Geography of West Africa* (London, 1955), p. 41. It is interesting to notice that Pedler does not think that the importance of rice in West Africa merits a special section in his book, while the latest version of the *Nigeria Handbook* (London and Lagos, 1955) has only two short references to this crop.
4. Compiled from the *Annual Reports* of the four West African territories and from F.A.O. statistics.

While considerable allowance must be made for error in the estimated figures, it is clear that in West Africa, Sierra Leone is easily the most important rice producer, though production in Nigeria is rapidly increasing. The large territory of the Gold Coast produces little more than the Gambia, chiefly in the Nzima area of the south-west, though, as in Nigeria, more attention is now being paid to this crop. Cultivation in Nigeria is increasing rapidly, even in the south where the staple foods have traditionally been cassava and yams. Thirty thousand acres were opened up for rice-farming in eight years (1945-53) in Ogoja alone, while Onitsha Province, also in the Western Region, is advancing rapidly. Experiments are now going on in the Niger delta in Rivers Province and in Warri where steady yields of 900 lb. of padi per acre are being reaped. Even so, the major producing area is still Sokoto, in the north-west, where some 75,000 acres are under swamp-rice, while other swamps along the rivers Niger, Kaduna and Benue are also being developed.

We find a marked change of emphasis when we consider the Gambia and Sierra Leone, for in both these territories rice forms the staple food of a large section of the people. Little upland rice is grown in Gambia but swamp rice is grown extensively on the *banto faros* (riverine swamps) of the middle river. There is little doubt but that more would be grown, for imports of rice are still necessary, but for the great financial attraction of groundnuts which form the Gambia's chief export. The groundnut acreage is about 210,000, and that of the chief "upland" crop, millets, 150,000; and these crops are grown by the men while rice cultivation is regarded as women's work. Recent attempts to stimulate production have had limited success.

Even so, it is clear from what we have already said that rice production in West Africa is increasing, and this is especially true of Sierra Leone with which the remainder of this article will be concerned. Rice forms the staple food of most Sierra Leoneans, and rice cultivation (carried on especially by Temne and Mende farmers) has gone on for a very long time. Until the latter part of last century practically all the rice grown was upland rice, and considerable stimulus was given to upland rice-farming by the pacification of the territory achieved by the British, which culminated in the establishing of the Protectorate by ordinance in 1896, and by the construction of the railway during the first decade of this century.

Upland rice, easily the most important crop grown in Sierra Leone, is grown under the bush-fallow system so well known in other parts of the Tropics, chiefly in the areas which naturally would be forested; little rice is grown in the "savannah" country (Fig. 1) where the staple crop is millet. Unfortunately, the soils are almost everywhere poor and degraded, as they are lateritic, acid (pH 4-6), and deficient in potash, phosphorus and calcium, as well as in other essential nutrients and micro-nutrients. This means that in many parts of the Protectorate farms are incapable of producing reasonable crops of rice for more than one year, so fresh clearings have to be made each year when the old farms are either sown with groundnuts or millet, or are planted with cassava and left to return to bush. Pressure of population is reducing the length of fallows to a dangerous extent — in some areas it is now no more than three or four years.[1]

Such has been the demand for rice-farm 'bush' over a long period of years that there is now almost no virgin forest remaining in Sierra Leone (Fig. 1). Secondary bush is the rule almost everywhere. This means that a very dangerous

1. See H. R. Jarrett, "Lunsar. A study of an Iron Ore Mining Centre in Sierra Leone", *Economic Geography* (1956), pp. 153-161.

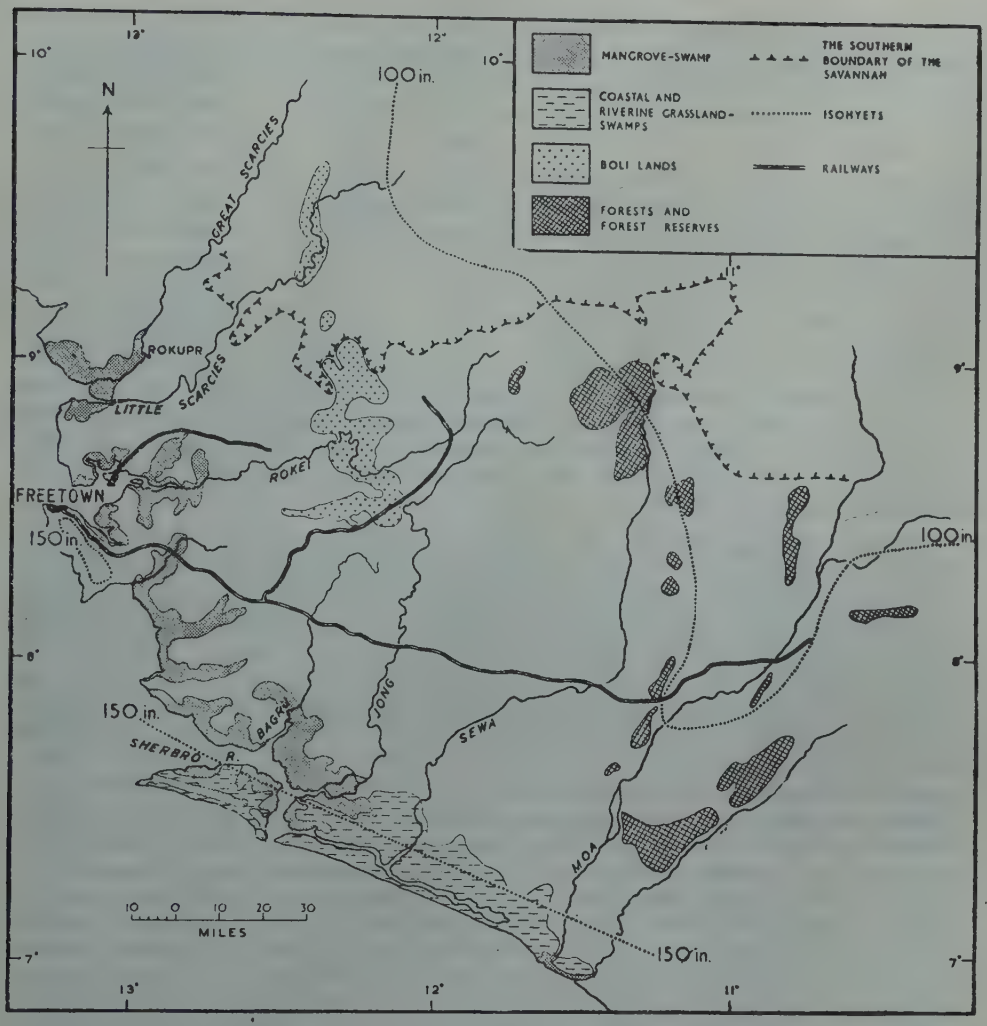

Fig. 1. Sierra Leone: elements of the physical landscape which affect rice growing.

situation is threatening, for the over-farmed upland soils are less and less capable of nourishing a population which is increasing noticeably (1931 census: 1,768,480; 1947-8 enumeration: 1,858,275; an increase of 5·8%). Yields may be no more than 400 lb. of padi per acre, a ridiculously low figure when one considers the labour involved, and it is not surprising that for some time overall yields have been extremely disappointing. An estimate published in 1951 suggested that there was a total annual production of 271,000 tons (216,000 on the uplands and 55,000 in the swamps)[1] which permits a per capita daily consumption of 0·83 lb. as compared, for instance, with the Hindu rice-eater's 1·24 lb. This clearly reflects a low level of nourishment, and His Excellency the Governor called in 1948 for production to be doubled in five years. It is interesting, in the light of this, to examine trading figures in rice over recent years.

1. *Soil Conservation and Land Use in Sierra Leone* (Freetown, 1951), p. 18.

TABLE 2: SIERRA LEONE: EXPORTS AND IMPORTS OF RICE, 1949 - 55.

	IMPORTS (CWT.)	EXPORTS (CWT.)	NET MOVEMENT (CWT.)
1944	0	5,980	5,980 EXPORT
1950	1,005	1,560	555 EXPORT
1951	21,680	1,740	19,940 IMPORT
1952	0	5,980	5,980 EXPORT
1953	108	13,260	13,152 EXPORT
1954	91,722	1,465	90,257 IMPORT
1955	421,300	34	421,266 IMPORT

The present position is clearly unstable and disappointing, and the wide variation from year to year cannot be attributable to climatic causes. The situation appears to be worsening, and may at least in part be attributable to the fluid economic and social conditions consequent upon the widespread discoveries of diamonds in the Protectorate.[1]

Can anything be done to remedy this position? The Department of Agriculture believes that it can, and has for some years been advocating the restriction of upland rice-growing and a greater concentration on swamp-farming. It is estimated that there are half a million acres of swamps in Sierra Leone, including mangrove and perennial, fresh water and *raphia*-swamps, together with flooded grasslands (Fig. 1). This is no mean figure, and there is no doubt but that if wisely used these swamps could bring considerable wealth to the country; there could almost certainly be surpluses of rice for export each year. Grasslands which are flooded during the rains account for about 300,000 acres, some of these grasslands lying inland and some being coastal. Of the mangrove swamps, about 137,000 acres lie in the southern provinces in the Bagru and Sherbo River country, while of this total possibly 12,000 acres are at present cultivated. The greatest development of swamp rice-farming so far, however, has been along the mangrove swamps of the Scarcies River in the north, where about 40,000 acres may be under rice during the rains. Most of the land, indeed, which it is practicable to cultivate without water control to combat salinity or flooding, is used. Swamp yields are variable as they are on the uplands; different strains of rice give markedly different yields, while the fertility of swamp areas is by no means constant. But results are markedly better than on the uplands; in the Colony, for instance, yields have ranged from 720 to 1,745 lb. of padi per acre, while the fertile riverine grasslands of the south-west return more constant yields, generally between 1,500 and 1,800 lb. The inland swamps vary between 1,000 and 1,900 lb., with 1,500 as a rough average, while the Scarcies yields are generally between 1,300 and 1,800 lb. Under water-controlled conditions yields as high as 3,190 lb. per acre have been recorded, but as we shall see later, water control raises acute problems of its own.

It must inevitably be a matter of surprise that so little advantage has hitherto been taken of the swamp resources of Sierra Leone in contrast to what has happened elsewhere, notably in South-East Asia. There appear to be several reasons for this neglect, a prominent one being that the population pressure is in no way comparable in the two cases. If we accept the 1953 estimate of 2,000,000

1. A similar condition exists at present in the oil palm industry. See H. R. Jarrett, "The Oil Palm and its Changing Place in the Economy of Sierra Leone", *Geography* (Sheffield, 1957).

inhabitants for all Sierra Leone[1] we can calculate an overall population density of 71·4 per square mile; this is hardly of the same order as, for instance, overall densities of 112·5 in Malaya, 319·7 in Ceylon, and 790·1 in East Pakistan, while according to Gourou, parts of the Tongking delta carry no fewer than 3,630 persons to the sq. mile (overall 1,166).[2]

There are other reasons for this tardiness in swamp development, chief among which must rank traditional prejudice stemming from ignorance. The inertia of tradition is often enormously strong among the uneducated, and great forces are needed to overcome it. This tradition is also important with regard to the palate; Sierra Leoneans have acquired the taste for upland rice and they will not eat swamp rice if they can help it. It is also true that swamp-farming demands considerably greater effort than upland farming; the initial clearance is more difficult,[3] weeding is more arduous, insects (particularly mosquitoes and leeches) are more troublesome, while there is also the extra effort which may be necessary to prepare nursery beds. Only the one crop can be grown during the rains, for there can obviously be no interplanting of secondary crops in the traditional manner, though such crops can be successfully grown under irrigation during the dry season. It is also true that successful swamp-farming demands a higher degree of control over variable factors than the villagers of Sierra Leone are capable of. Annual rainfall variations are great, and such variations lead to wide fluctuations in the degree of flooding from year to year which may be catastrophic without some measure of flood control, while another troublesome point is that the rank natural growth encountered in swamps cloaks wide variations in fertility. Many swamps which are simply floored with sandy deposits washed down from the neighbouring uplands have an insignificant clay fraction and are extremely infertile, so that when they are cleared and drained they simply dry out and become almost sterile.

We must not forget, moreover, that swamps do have other uses than as potential rice producers. The *raphia* swamps, for instance, produce the valuable *raphia* palm which has a very wide variety of uses, and it would be foolish in the extreme to cut off adequate supplies at the source, while all swamps have a very considerable value as they conserve water through the dry season. In effect they act as gigantic sponges, soaking up the water during the rains and releasing it slowly throughout the dry months. If all the swamps were drained, water supply at the end of the dry season would present an acute problem; even now in many areas it is far more serious than it was because of interference with the natural vegetation.

Even the strongest traditional prejudice can be overcome, however, and after a few pioneers had demonstrated on the Scarcies the tremendous superiority of cleared mangrove-swamps over the uplands as rice producers many farmers began experimenting with swamp-farming. Tidal mangrove-swamps were first developed by Temne farmers at the mouth of the Little Scarcies River about the year 1880. At first the traditional upland methods, including direct planting, were used, but after heavy losses of young seedlings through wash-outs and the depredations of

1. *Sierra Leone, 1953* (Colonial Reports, Annual; H.M.S.O., 1954), p. 8.
2. P. Gourou, *The Tropical World* (Trans. from the French by E. D. Laborde: London, 1953), pp. 99-100.
3. The felling and clearing of mangroves has become a very specialized occupation among the Temnes. Gangs of Temne fellers are widely employed, and no satisfactory alternative has yet been found. This means that the pace of clearing is slow and, as other less arduous, jobs are now available, these specialists are becoming fewer and it is not easy to get this work done at all.

crabs and fishes the Asian practice of nursery culture was introduced. In 1921 two specialists from India were called in to advise on the future of the swamp-rice industry, and as a result of their recommendations the system evolved on the Scarcies was introduced successfully into the tidal swamps of the Southern Province. Later surveys[1] confirmed the suspected possibilities of these southern swamps, and it was largely these surveys which prompted the optimistic outlook which envisaged a rice-exporting Sierra Leone emerging within a decade after the close of World War II.

The native farming calendar varies between different areas. In the Scarcies swamps hoeing goes on in March and April, primarily to remove the salt-resisting grass *Paspalum vaginatum* which is the only weed of any note. The seed is sown in upland nurseries in June and July when the rains are established, so that the seedlings are ready for transplanting during August and September. Growth is then very rapid, and the main harvest begins in December. On the southern grasslands activities commence in February and March, when the grass is burnt and re-burnt after a further three weeks. The grass roots are hoed up and taken to the edge of the farms, and the seed is sown broadcast in April and May; during the latter part of May and June weeding is essential, but after that the flood-waters render it unnecessary. Again, the harvest begins in December. It is interesting to notice that it is possible to grow an 'early dry season' rice crop on the low ground near the rivers, and for this purpose seedlings are grown in nurseries during October, ready for transplanting in November and December as the flood waters recede. The harvest is ready by March or April. Despite the relatively restricted amount of swamp-farming, therefore, there is enough practical experience to suggest that the policy of encouraging this activity is the correct one. The corollary is, of course, that as the uplands are freed from rice growing, the period of bush fallow can be lengthened and more suitable upland crops grown.

A considerable amount of research and experiment has been conducted into the growing of swamp-rice, and the early activities of rice research officers were directed towards producing genetically pure seed, for there is clearly much wastage involved in sowing long-stemmed and short-stemmed, early-ripening and late-ripening seed mixtures as was the prevalent practice. Increased yields were assured when farmers knew exactly what variety of seed they were planting.

Experiments have also been conducted at Rokupr with a view to ascertaining the value of water control. Rokupr, the headquarters of rice research in West Africa, lies about twenty miles from the mouth of the Great Scarcies River, and even here the water is noticeably saline during the dry season; during the rains the increased supplies of fresh water push the salinity limit considerably farther downstream, almost to the sea. It is not difficult to envisage the advantages which might be derived from empoldering and full water control, for the depth of flooding can then be regulated, young seedlings are in no danger of being swept downstream before they are firmly rooted, losses through crabs and fish may well be lessened, while dry-season crops may be grown on the rice swamps under irrigation.

In 1943 a start was made in the erection of bunds and sluices around selected plots on cleared mangrove land at Rokupr so that complete water control could be achieved, and this programme of work was completed before the 1944 sowing. It was a matter for rejoicing when outstandingly good yields in 1944

1. R. R. Glanville, "Rice Production in Swamps", *Sierra Leone Agricultural Notes*, No. 7 (Freetown 1938); G. M. Roddan, *Report on...Rice Lands...in the Southern Province* (Freetown, 1938) and *Report on...Rice Lands East of the Bagru River* (Freetown, 1939).

seemed to justify the experiment, but yields thereafter unexpectedly declined sharply to such an extent that by 1947 much of the bunded land was completely unproductive. The rice seedlings died soon after they were transplanted from the nursery. It was not until tidal conditions were restored in 1949 that productivity recovered, and further experiments have shown conclusively that complete water control is not, in fact, desirable. The following statistics illustrate the general pattern of events.[1]

TABLE 3: PADI PRODUCTION (POUNDS PER ACRE)

		PLOT 10	PLOT 11	PLOT 13	PLOT 14
FIRST YEAR OF POLDERING	1944	3,180	2,280	2,736	2,172
WATER CONTROLLED	1945	2,100	1,458	2,298	432
	1946	1,770	1,302	2,550	210
	1947	1,020	162	2,016	0
FIRST YEAR OF MODIFICATION	1948	540	288	1,320	15
TIDAL CONDITIONS RESTORED	1949	2,020	1,440	2,625	1,640
WATER CONTROL RE-INSTITUTED	1950	1,740	1,220	2,680	2,670
WATER CONTROLLED	1951	970	580	950	1,000
TIDAL CONDITIONS RESTORED	1952	2,650	2,370	2,540	2,480

Not unnaturally, these unforeseen results stimulated further research into the underlying causes, and it was soon apparent that the trouble lay in an accumulation of toxic compounds which rendered the soil and groundwater extremely acid. Rice is tolerant of acid soils, and can be grown satisfactorily where the pH factor is greater than 5·5, but tests taken during 1947 and 1948 showed pH values ranging from 2·8 to 3·8. A further interesting point is that bunding has been successfully carried out in other swamp areas, including mangrove-swamp of the *Avicennia nitida* type, so that the development of these toxic compounds appears to be related to the *Rhizophora racemosa* mangrove, the decay of which under anaerobic conditions seems to lead to the formation of hydrogen sulphide and ferrous sulphide. It is the ferrous sulphide which is deposited on the rice seedlings and destroys them. Subsequent oxidation of these sulphides produces toxic accumulations of sulphates, including the uncommon hydrated ferrous sulphate, $FeSO_4.7H_2O$, which during the dry season appears on the surface of the soil as an efflorescence. Sulphate of aluminium has also been detected, and traces of insoluble basic phosphates of iron and aluminium, so that there is probably a corresponding reduction in the amount of available soil phosphate. Chemical analyses showed 12-15% concentrations of oxides of iron in the soil, and up to 1·4% of sulphates in the groundwater.

One of the most interesting features is the rapidity with which these noxious compounds are removed as tidal conditions are restored, and the table above shows good rice yields in 1949, the first year of full tidal restoration. Later experiments confirmed this, and also suggested that the most satisfactory form of control is a low bunding which traps the water at low tide and encourages deposition of silt but permits the high tides to wash over in the normal way. Experiments are still continuing.

We have already commented upon the acidity of the swamp soils and have seen that there is a danger of lowering the pH factor too much even for rice

1. *Annual Report of the Department of Agriculture for* 1952 (Freetown, 1954), p. 14.

when water control is instituted. Any method of reducing soil acidity is to be welcomed, and experiments have been conducted to show whether applications of lime would be beneficial. Notable deposits of oyster shells occur at various places around the Colony coast, and when burnt and crushed these yield 40% calcium oxide. Shells treated in this way were applied at the rate of ten tons per acre to small test plots near Wellington, and produced a marked response in the growth and yield of rice as compared with untreated plots. There are probably various reasons for this. In the first place the pH of the soil was raised to 7 (neutral); again, it is possible that some of the calcium may have been directly used as a plant nutrient, and there is a notable lack of calcium in Sierra Leone soils because of the intense leaching.[1] It is also known the applications of lime to a heavy, impermeable soil promote flocculation, and render it more permeable; this is brought about by a base-exchange process whereby hydrogen and sodium in the soil are replaced in the soil absorbing complex by calcium. These processes have yet to be studied in detail with regard to the swamp clays of Sierra Leone, but of the beneficial results there can be no doubt and in the Wellington experiment the benefit of the application of the burnt shells was notable for at least two years. Unfortunately local supplies of shells are limited, and experiments have shown that applications of imported lime, though markedly beneficial, may not be economic.

Further experiments are also being conducted on the *boli* lands. These are large grassy swamps which stretch in some cases for as much as thirty miles on the pre-Cambrian sedimentaries of the Rokel River Series. Mechanized farming trials on them are showing promising results.

It is noteworthy how the spread of swamp rice-farming is leading to disruption of traditional ideas and practice regarding land rights. Owing to the shortage of virgin-forested uplands, settlers or 'strangers' can customarily be granted only defined usufruct rights over an area they wish to farm; for instance, they may grow rice and groundnuts and retain the harvest, but the produce from oil-palms on the farm may remain the property of the original owner. The stranger may be dispossessed by the original owner at any time subject to rights with regard to standing crops.

Clearly such uncertainty of tenure is unsuited to mangrove-swamp farms which require enormous labour to clear, and, in any case, population along the Scarcies swamps was so sparse originally that farming rights (as opposed to chiefdom rights) were virtually unknown. When it was realized that suitable swamps were far more valuable than uplands, as they could be cultivated annually instead of about one year in seven, while yields were also higher, a migration of people set in downriver into Mambolo and Samu chiefdoms.[2] The traditional idea that each town held its land as a unit within a chiefdom broke down as swamps were opened up, though 'strangers' seeking land still had to observe the customary courtesies. An introduction must now be sought to the Paramount Chief from a person of standing within the chiefdom; customary presents (a piece of cloth, some helds of tobacco, or even money) may then be given to the Chief, after which permission to farm may be granted. But thereafter the great point is that, when once a virgin area is cultivated after due permission, the cultivator owns the rights to cultivate in perpetuity, and he cannot be dispossessed. The land can even be

1. This has been demonstrated by chemical tests carried out in the Colony. The bed-rock, norite, carries 18·8% of CaO, but leached layers near the norite contain only a trace. The low-grade bauxite found by Dixey near Wilberforce has none at all. On the other hand the insoluble Al_2O_3 increases from 17·9% in the norite rock to 41·5% in the layer near the rock, and to 51·1% in the bauxite mentioned.

2. Mambolo lies to the south, Samu to the north, of the Scarcies estuary.

inherited by the next-of-kin. This is a revolutionary change in contemporary social economy.

While land is not rented according to the Western conception, it can be lent if a tenant pays rent, though the tenant has no security of tenure. Land can also be pledged to redeem a debt, and this is a serious problem. Where farmers have such small cash margins, a sudden catastrophe — a court case or sickness, for example — may necessitate a loan, and it is not unusual for farms to be pledged for this purpose. The farm is handed over in its entirety, and the money-lender enjoys all rights over it until the loan is repayed in full. Obviously, with his main source of livelihood denied him, the farmer may find his plight worsening rather than improving as time passes.

In the more recently developed southern swamps the situation is quite different. In many cases money loans have been advanced to farmers to enable them to clear land and make a start, and the loan is often recovered by the District Council in kind after the harvest. More often, land is cleared by mechanical means and then let to farmers at an agreed rental which again may be paid in kind. As these areas originally carried only a very sparse population these arrangements do not interfere with local practice, and farmers are now moving into these areas from other parts of the Protectorate.

Enough has been said to show that if present schemes prove successful Sierra Leone will shortly be producing enough rice to satisfy her own needs while she should also have a surplus for export. It is ironic that just at the time when this possibility lies within reach, the attention of so many farmers should be diverted by the search for diamonds. The new diamond rush in Sierra Leone is having an adverse effect upon agricultural production, and many rice-swamps are now lying idle, and we have already noted the effect of this with regard to the present-day rice situation. The eventual outcome of this unusual situation will be awaited with the greatest interest, especially by the major rice-exporting countries, who may see yet another door closed against them in West Africa in the near future.

AGRARIAN AND SOCIAL TRANSFORMATIONS IN THE TAMOURT BASIN, MAURITANIA

By C. TOUPET

A paper presented to the *Congress of Tropical Geography* held under the auspices of the *International Geographical Union* at Kampala, Uganda, September, 1955.

Translated from the French by Nora Toupet.

This region is marked by the deficiency and irregularity of its rainfall. At Moudjéria the yearly average is 10 in., with the yearly totals varying between 2 and 16 in. This serious handicap is fortunately compensated by the geological structure of the region. The Tamourt Basin drains the entire western part of the Tagant sandstone upland of Ordovician age by means of tributaries which make use of subsequent depressions and the main stream which follows a faulted trench. There is also an important water supply at the junction of the upper and lower sandstones so that throughout the year water is to be found at very little depth over the whole length of the valley. It gives birth to a vegetation particularly dense for the Sahel and essentially composed of acacias *(Euphorbiaceae)*, grasses, and date-palms. Thus it permits the development of a relatively stable economy and the localization of a growing population.

Occupied ever since the Neolithic and densely populated in the Middle Ages by negro peasants (which is testified by ruins of dwelling-houses, by discoveries of mill-stones and pottery, and by the Arab chroniclers), the country was first a prey to Berber pastoralists, and then to Arab pastoralists whose quarrels lasted until the nineteenth century and whose appearance in these agricultural lands probably coincided with a deterioration of climatic conditions. In this tormented history lies the origin of the feudal social structure a knowledge of which is essential to an understanding of our subject, for, even to-day, although modified by French influence, the division into social orders finds expression in a corresponding division of occupation. At the head of the community strut the noble warriors or marabuts, plotting, meditating, praying, but refusing to undertake any manual work. Then come the Zenagas or Tributaries, ancient Berber tribes subdued by the Arabs and obliged to pay tribute. As a rule they are cattle-breeders but they do not disdain to plant date-palms. After them come the specialized castes: blacksmiths, shoemakers, musicians, and then the Harratin or liberated slaves, descended from the first negro peasants or from the many negroes seized by the Mores south of the river Senegal. Finally, there are the "Servants" or Abid, who are negroes too. These latter two classes alone work on the land and it is they who assure the existence of the masters.

The Pax Gallica which was established during the first quarter of the twentieth century was conducive to the spread of settlement into every part of the country and a corresponding growth of population. The pastoralists wandered about without fear, the agriculturalists were permitted to clear new soils in the rich inundated valleys and even in the *hofrats*, the large basins where the rains, though of short duration, enable the sand to bear some harvests. It is always rash to estimate densities in a poorly surveyed country which by its nature is little

subject to statistics, but a density of two per sq. kilometre may not be far from the truth, rising to 30 per sq. kilometre in the central parts of the valley when the population, nomadic and sedentary, is concentrated there during the month of July for the date harvest, the *guetna*. A study of the ethnic distribution confirms this growth and shows that the basin of the Tamourt has acted like a mustard poultice on the tribes of neighbouring territories. The traditional inhabitants are the Kounta and the Abakak. Then, from the eastern plateaux of the Tagant came the Tadjakant; from the sandy Trarza, the Torkoz; from the desiccated Adrar, the Smasides and the Ideychilli. These natural and historical factors engendered the juxtaposition of two ways of living: that of the sedentary agriculturalist and that of the nomadic pastoralist, with numerous exchanges between the two.

It is to be noted that some tribes, like the Torkoz, are exclusively pastoralists, whereas the Kounta effect a symbiosis, being both cattle-breeders and agriculturalists.

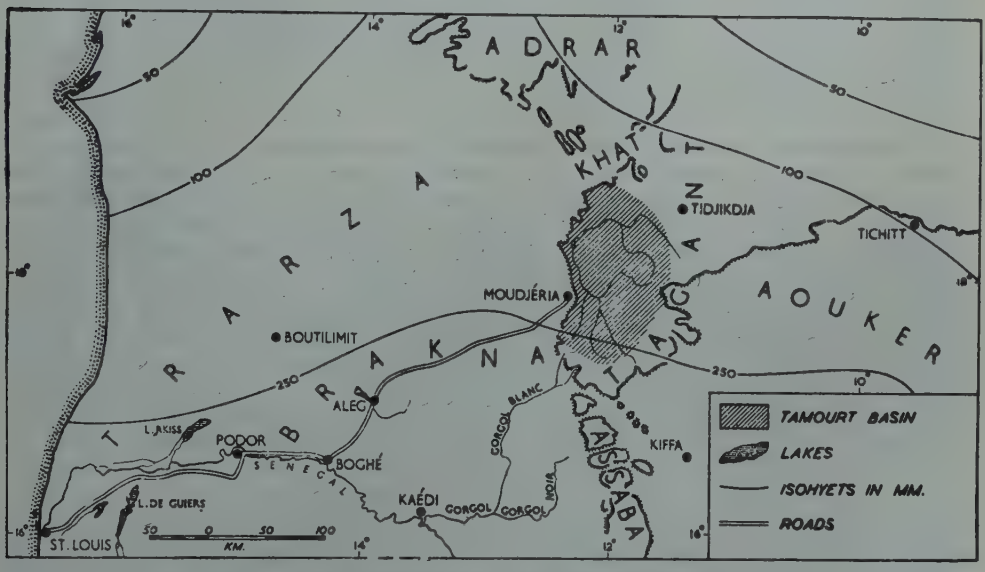

Fig. 1. Key map of the Tamourt basin.

The whole life of the nomad is based upon the conception of the value of herds as capital. Wealth is estimated according to the number of cattle a man possesses. There is no pastoralist who would not piously keep alive his oldest and most decrepit animals. Slaughter is rare and limited to feasts and receptions for honoured guests. The nomads are essentially breeders of horned cattle, and particularly of sheep and goats, which find their feed in the herbaceous and shrub vegetation. The Mores of the Tamourt possess some camels: the camel is the noble's riding animal and it is also the beast of burden, as is the ox with the Peuls. But the camel is here at its southern limit for both climatic and pathological reasons, namely the existence of flies bearing a disease analogous to trypanosomiasis. Although water is found everywhere at little depth all the year round, the nomads' lives are regulated by the search for pasture. The rallying point of all the nomads is the Basin with its palms loaded with dates during the *guetna* in July. Then in the wet season (end of July to the end of September) the herds are removed from the lower grounds which, inundated and forming breeding places for mosquitoes and flies, are soon transformed into fields. The breeders then go up to the high

ground covered with vegetation: this is the happy period during which the humps of the camels grow fat. About the month of November some breeders approach the farm lands to harvest millet. Finally, during the cold season they return to the valley by short stages. On the whole, the wanderings of a group of families do not exceed a diameter of 40 to 50 kms.

The reasons for these nomadic movements must be sought not in any environmental compulsion but in more general and human factors. First, it is the best means of utilizing the soil. It permits the establishment of an equilibrium between the duration of the grazing period and the number of the animals on the one hand and the conservation of vegetation and soil on the other. In the Tamourt there is no such thing as over-grazing. Second, the nomads like to be free; they want to be able to escape from social and administrative constraint, and even from the expensive constraint of hospitality. An example will enable us to understand better the character of these small wandering groups. The Haiballah II follow this nomadic existence in the Foo basin, whose diameter does not exceed 8 kms. In this *hofrat* about 250 persons move their tents by degrees as the pastures are grazed. None of them want to establish themselves definitely in a clay house and utilize the services of a shepherd; the owner wants to stay with his herd and follow it in its search for pasture.

Contrasted with the nomads are the farmers, attached to their fields. Of course in a region where famine is a constant menace, there is only subsistence agriculture based on millet and beans, together with dates, some vegetables and, in the north, some wheat. Two systems of farming are practised for the deficiency of rainfall prevents dry agriculture: (1) flood culture; and (2) irrigated culture under palms whose role is quite accessory. Flood culture consists in utilizing the powerful sheet of water which at certain times inundates the major part of the wadi and deposits organic remains and soil brought from the upper course of the river. By degrees, as the flood-waters retreat, the inundated land is brought into cultivation by the "Servants" (Abid). Three factors are of extreme importance in this process: (i) the morphology of the land; (ii) the duration of the inundation which influences the choice of crops: millet can be cultivated upon a soil which has been flooded for only 8 days whereas wheat needs a month of inundation; (iii) the nature of the soil. We can distinguish clay soils, sandy-clay soils and then sandy soils in turn as we pass inland from the river bed. The pH values which I have found vary between 7 and 8, indicating that these soils are suitable for cereals. This flood culture is practised mostly along the wadi. The Arabs have introduced earth dams which they build in the steepest wadi in order to retain there a sufficient quantity of water to permit flood culture.

As soon as the water recedes, the farmers with *dabas* (a sort of hoe) dig holes 20 cms. apart, in which they sow grains of millet or beans, stamping down the earth with their feet. Then the crops are left to mature with the aid of Allah, while the women and children scare off crickets and birds by screaming and throwing stones with catapults, and the men surround the field with a *zeriba* of thornbushes to protect it against cattle.

By the end of November the first fields of millet are harvested. Yields are on the whole high: 1 kg. of millet sown produces upon an average 300 kgs. Wheat, harvested at the beginning of January, yields a return of forty for one. On the whole there is little real farming technique apart from the construction of dams and some notions about fertilization. The Mores know, particularly, that they must sow beans at the same time as millet in order to restore nitrogen to the fields. It even happens that some graze their herds upon the future field, thus permitting a rather heavier application of manure. But in these inundated

regions fertilization is really effected by the flood water, which deposits silt brought from regions further upstream.

Irrigated culture owes its inception to the abundance of palm-plantations in the valley, which afford a protective shade to the more delicate crops such as wheat, vegetables and tobacco. However, certain conditions are necessary for the success of this method. The palms must be at a certain distance one from another (about 10 m.) and they must be mature (about 10 years) in order to permit work being carried out beneath them and yet give sufficient shade. The techniques of irrigation are rudimentary: they consist in digging shallow wells (between 1 and 6 m.) and *shaduf* from which channels run across the plantations; from these water is carried to the crops in *delous* (goat skins) and sprinkled with the hand.

The palm plantations are traditional: they represent a fundamental subsistence culture and a joy of life. When I remarked to a young More that his palms were planted too close together, he replied that it was nicer like that and later he would be able to rest in their shadow with his father. Still, topographic conditions (an abundance of slightly elevated flat ground along the *bathas*), pedological conditions (sandy soils) and hydrographic conditions (shallow flooding) lead us to hope for an expansion of this form of agriculture. However, at present techniques are rudimentary, a date-palm bearing annually only from 50 to 100 kgs. of fruit.

These modes of life are thus reflected in the landscape: on the one hand are the valleys under crops and palm plantations, with bushes and swamps between; on the other hand there are the uplands covered with grasses and shrubs, which are the haunts of the nomads. This study also permits us to characterize a dual and archaic, but extensive, economy in which the Harratin and Abid alone till the ground. The white More, being a nobleman, only superintends the increase of his herds and claims part of the harvest. Moreover, agricultural or pastoral methods are rudimentary. Finally, cattle-breeding is in no way integrated with agricultural practice. So we find here two ways of living economically distinct but socially integrated.

The result of this system is that production only equals consumption one year out of five, and millet has to be imported from Senegal. Malnutrition is widespread. The principal food of the pastoralist is milk, to which he adds a little millet bought in exchange for cattle. The agriculturalist who owns some cows and sheep also drinks milk but millet is relatively more important in his diet than in that of the nomads. Both pastoralists and agriculturalists are obliged, towards the end of the season, to supplement their provisions with wild grasses. Dates are an indispensable and substantial food. Finally, very little meat is consumed. On the whole the diet is wholesome, thanks to the milk and the dates, but insufficient in quantity and doubtless in nitrogenous elements.

The "Servants" and the Harratin tend to emigrate either temporarily during the off-seasons in order to earn a little money, or even permanently to better themselves in neighbouring territories. So this country is losing its working population, whereas the nobleman is often still refusing to engage in manual work (this is only true for the Tagant; in the other regions of Mauritania many noblemen have started to work).

Some remedies for this situation have been attempted already: they are of two orders: (1) increasing agricultural production. This is effected by improvement, and not in the first place by increasing the numbers of cattle; by increasing the acreage of agricultural land through the construction of dams and irrigation

canals; by introducing new plants such as vegetables, cotton and tobacco. An experimental station of the Agricultural Service has already recorded results in its attempts to introduce new palms. (2) Fostering social evolution, by convincing the Mores of the nobility of labour and permitting the "Servants" and the Harratin to become tenants, share-croppers or even owners of the fields which they cultivate. An experiment has just been tried in which share-cropping contracts are drawn up between master and servant and the results are very promising. This transformation will stop an emigration, which is as grievous in the town as in the country. The Tamourt Basin will then be able to realize the vocation which Nature reserved for it, namely, to become the granary of the North supporting a balanced and contented population.

TROPICAL EAST AFRICA

POSSIBILITIES OF DEVELOPMENT

By ERNST WEIGT

Two facts pre-eminently require geographers to take an especial interest in the possibilities of development in East Africa. First, there is the Point Four Programme for the improvement of underdeveloped regions, among which East Africa must be counted, and second, there was the complete failure some years ago of one of the boldest of development schemes, that for growing groundnuts on a large scale.

First, let us examine the region we are going to hear about. It is the central part of Eastern Africa from about 4°N to 10°S, between the Indian Ocean on the one side and the distinctive line of the lakes in the Central African rift valley on other. Politically most of it belongs to the British sphere (Uganda, Kenya and Tanganyika Territory), but in Ruanda-Urundi Belgium reaches from her Congo colony into East Africa. East Africa, thus defined, comprises about 700,000 sq. miles with more than 20 million inhabitants. The position between 4°N and 10°S puts East Africa into the inner tropics, but this must not be held to imply the usual concomitant of a warm climate at the same time always wet. Owing to its proximity to the Asiatic continent East Africa, even at the equator, is a country with a regular alternation of wet and dry seasons, a regime reflected in the East African savannas and dry forests in contrast to the evergreen tropical forests of the Congo Basin further to the west. Only the southern part of Uganda is to a certain extent an exception to this rule. It has rains fairly well distributed throughout the year, and this allows the growth of evergreen vegetation. Everywhere else we find a regular alternation of distinct dry and rainy seasons, two of each in the year near the equator but changing to a simple sequence of a more or less rainy half year and an equal period of complete dryness. On the whole rainfall is scanty in East Africa. Only on the southern and eastern slopes of the fault-scarps or rift valleys and in the permanent mist zone of high mountains is humidity sufficient for evergreen forests.

By far the largest stretch of East Africa receives only between 20 and 30 in. of rain while large tracts of the north-east have less than 20 in. Rainfall averages, in any case, are of little value as precipitation varies greatly from year to year. We have to remember, moreover, that with the high evaporation consequent on tropical temperatures the effectiveness of the rainfall cannot be compared with that of the temperate zones. The recorded yearly evaporation from open water surfaces in East Africa averages about 60 in. and even reaches 100 in. in some places. Efficient agriculture, therefore, is rarely possible with rainfall of less than 30 in. and even stockfarming needs at least 25 in. This relation between rainfall and evaporation over large parts of East Africa finds expression in the fact that in Kenya and Tanganyika two-thirds of the country is nearly or completely uninhabited. In Kenya this is especially true of the dry north-east, in Tanganyika of the south-west. There is, in fact, sufficient rain for agriculture for part of the year, but during the rest surface water is missing. The inter-dependence between man and water supply is shown still more clearly in Tanganyika where seven-tenths of the population is concentrated in favoured parts of the country covering only one-tenth of its area.

After this crude characterization of East Africa as a part of the world the utilization of which is primarily dependent on quantity and distribution of rainfall, we proceed to those aspects of our topic which are commonly connected with 'development'. Usually this is considered from the economic viewpoint with an eye to increase in production—although this is certainly too narrow a view. Not infrequently cultural development of a people by education and teaching is a necessary preliminary to higher productivity. Such cultural advancement is least necessary for the most primitive form of land use, the mining of mineral deposits. Therefore, in all the ten-year plans of the East African colonies geological research takes an important place. Gold is washed or mined in many parts of East Africa, particularly in Tanganyika. Kenya possesses, among other minerals, cyanite in the south-east, inexhaustable masses of soda carbonate in Lake Magadi in the East African rift valley, tin between the great lakes, and south of Lake Victoria good quality diamonds in quantities which could easily supply more than the ten per cent of the world's consumption which has until now been granted to East Africa. Uganda has copper deposits in the west, but they will become important only when the railway from Kampala westward has been built. A branch line has already been constructed since the war from the Central Railway

to the lead mines in south-western Tanganyika. Mica is widely distributed and uranium is known. Large coal deposits in Southern Tanganyika, with iron ore in the same neighbourhood, only require a market in the vicinity to make the construction of a railway a paying proposition. Possibly the plan to give the North Rhodesian copper district a direct outlet to the east may be a chance for the development of mining in south-eastern Tanganyika. But even if all the mineral ores in the region could be developed, they could never play more than a minor part in the development of East Africa.

Rather will the development of East Africa continue to be fundamentally dependent on agriculture, and for this climatic conditions are of supreme importance. Rainy and dry seasons decide the rhythm of sowing and harvesting as well as the plants which can be grown. These have to be drought resistant or at least possessed of a short growing season, so it is not surprising that the only product of East Africa which has obtained any importance on the world market (one-third of the world output) is the fibre of the sisal agave or henequen, a succulent, drought-resisting plant originating in dry Yucatan. Sisal alone accounts for from one-third to one-half of the total value of exports from Tanganyika. In Kenya, too, sisal holds an important place in export. Without any questions there is still ample ground available for this cultivation. Its expansion depends much more on the possibilities of marketing the fibre than on the physical conditions of its cultivation.

Most important for the further development of East Africa is the fact that population is concentrated in relatively small, climatically determined regions, namely, in places favoured by ampler rainfall or its better distribution, e.g., around the shore of Lake Victoria, on the highlands above the rift valley, on the slopes of the volcanoes and mountains and along parts of the coast, as appears so clearly on Gillman's population map. These belts are especially important in the economy practised by the natives, only a small percentage of whom are pure herdsmen. Most of them are dependent on agriculture, but they hold the possession of stock in high esteem. Stock-raising is considered immensely superior to the cultivation of the soil, which is, therefore, mostly left to the women. Cattle are, however, of social rather than of economic importance. The number of his stock, and certainly not the quality, decides the social position of a man. It is his constantly increasing bank account, a means of acquiring surplus wives, who in turn bear girls, who can be married in exchange for more cattle. This, it is true, is considered by some to be too simplified a view of the importance of cattle in the life of the East African, but it is certain that only against a background such as this, deeply rooted in his thinking and feeling, can we attain an understanding of East African agriculture, both of its deficiencies and of its possibilities for its further development.

Only where the tsetse-fly makes cattle raising difficult or even impossible are the people preponderantly cultivators. In the other parts the activity of European veterinary officers, who, by eliminating this pest, permit the rearing of stock without limitation, has very often proved more of a curse than a blessing for the population as well as for the animals. Livestock now graze large areas which should be used to grow food for the population. Moreover, during the dry seasons cattle are often starved to death by thousands on the overstocked pastures. In spite of this, only in the most exceptional circumstances can the owner be convinced of the desirability of selling a proportion of his stock or of slaughtering even his surplus bulls or infertile animals. In spite of the high esteem in which livestock are held, only the nomads, and particularly the Masai, derive a nutritionally important part of their diet, namely blood and milk, from the animals: the mass of the population is almost completely vegetarian, growing food by a system of shifting cultivation with the hoe. The soil, tilled only superficially, is quickly exhausted. Manuring is practically unknown and is also very difficult to practise in a semi-arid country. The herds, because of the low carrying capacity of the pastures, have to move over large areas and even the manure they produce is dried out, dispersed to dust in the dry season and thus lost. So the agriculturalist must move to fresh plots leaving the exhausted land to regain its fertility only after a long bush-fallow. With the growth of population and the steady increase in numbers of cattle in recent years the soil has to be used at ever decreasing intervals. This loss of fertility is also accompanied by a predisposition to erosion by rain and wind. Moreover, the physical structure of the soil is changed fundamentally so that it is deprived of its extremely important water-retaining capacity. It dries up to a dust and is washed away by the rains of the succeeding wet season. Thus soil erosion has become a problem which bids fair to hinder all further development in East Africa. It is, therefore, easily understood that every extension of cultivation will only exacerbate this problem unless it is possible to introduce and enforce at the same time methods of soil preservation. How difficult this will be with uninstructed African peasants you may judge by the statement that in Kenya, even in the European farming areas which are by no means deficient in quality of soil and rainfall, only 4-8 cwt. of corn are harvested from the acre owing to inefficient farming practice, whereas on a neighbouring experimental station, with normal good husbandry, a yield of 32 cwt. per acre has been achieved.

The tribal areas, more than sufficient half a century ago, with a native population increasing as fast as soil fertility decreases, are becoming less and less capable of feeding the inhabitants. Nevertheless, this over-population in proportion to carrying capacity is welcomed by some European farmers. Only in this way, they think, can the ever-present danger of too little manpower for farms and plantations be avoided. Already 200,000 labourers are working on European farms in Kenya, and that with only 15 per cent of the European land under crops and only another 40 per cent being used as rough grazing.

The areas with ampler and better distributed rainfall are less endangered by soil erosion, especially if the country is flat as in large parts of Uganda. Its intelligent population has become to-day the second most important cotton producer in the British Commonwealth, whence arises the danger that the old subsistence cultivation may be neglected in favour of the commercial cash crop.

Intensive agriculture, practised according to the principle of keeping the soil in permanently good heart by manuring and soil conservation, has developed in East Africa only at very few spots. They are always found in areas with high population pressure, as on Ukara Island in the south-eastern corner of Lake Victoria, in the Matengo Highland and to a certain extent on the slopes of Kilimanjaro, where the limited acreage forbids shifting cultivation. Stable feeding, crop rotation instead of land rotation, soil conservation and in parts irrigation allow here a numerous population to enjoy a fairly high standard of living. But all these exceptions to the East African norm are found in regions favoured by climate and soil fertility. Notwithstanding, as these exceptions have arisen without European influence, they prove that the African is capable of solving the problem of keeping the soil in good heart continuously and obviating the danger of soil erosion at least in some places. First of all, such examples, especially in the relatively favoured regions, should be fostered carefully. Elsewhere the compulsion of nature is not usually strong enough to induce precautionary measures. But education and mild encouragement, together with the inducement resulting from visible financial successes could lead to permanent stabilization.

In other parts of East Africa, on the other hand, the African is completely dependent on the help and organization of the European. This is especially the case in those areas which, although they receive a total precipitation adequate for agricultural purposes, yet for part of the year are deficient of water on or near the surface. Here only the drilling of wells can help, but only seldom is the geological structure suitable. These circumstances are in no way alleviated by the lack of relief which hinders the construction of dams for reservoirs in which to preserve the rainfall of the wet season for use in the dry months.

In order to relieve the double pressure of man and livestock on the land in the favoured areas, the Government tries by dam construction to make it possible to rear cattle in the wet season outside the settled areas. Not until the water resources are exhausted in these remoter areas should herds be allowed to graze nearer the population centres, where the pastures have meanwhile been rested and recovered. But to give effect to these plans another problem of East Africa has to be solved, that is, the eradication of the tsetse-fly, which makes cattle rearing impossible in certain areas. In spite of some short term success by vaccination, so far the destruction of the bush is still the most effective means of combatting this pest. With the low carrying capacity of the bush pasture this means, however, an enormous work. At the same time, the wide-spread destruction of natural vegetation ensuing raises once again the fearful menace of soil erosion. So only in slow development, step by step, can population pressure in the congested areas be relieved by forming new population centres. Development of water resources, dispersion in congested areas to prevent soil erosion and, on the other hand, concentration of the widely distributed population at certain places in tsetse infested country in order to be able to keep the bush down—all have to take place in combination. Last, but not least, people have to be found who are prepared voluntarily to take the risks always connected with new settlements, besides which they must be willing to comply with modern methods of agriculture and to avoid overstocking lest they destroy the newly won land from the very beginning.

Thus, not the least of the problems involved in the development of East Africa is man himself, with his traditional habits and customs, his psychology seemingly so different from that of Europeans, and his mystic social esteem for the possession of cattle in a society where woman is merely a toiler on the land. The problem of development is, therefore, less one of economics than of psychology. Ways and methods are known of overcoming most of the natural circumstances which have hitherto prevented the raising of standards of productivity in East Africa, but the correct psychological approach can be induced only slowly by contact between man and man, a process necessitating the co-operation of the intelligent African himself.

CORRESPONDENCE

Division of Virus Research & Medical Zoology,
Institute for Medical Research,
Kuala Lumpur, Federation of Malaya.
29th September, 1955.

The Editor,
The Malayan Journal of Tropical Geography.

Sir,

The risk of introduction of yellow fever to Asia from the endemic areas of Africa or America has long been recognized, and special attention was directed to the problem by a conference of experts on virus diseases which was held at the Institute for Medical Research, Kuala Lumpur in February, 1954. Since then work has been undertaken in this Institute to assess the nature of the risk and to design protective measures. Vaccination is enforced by the International Sanitary Regulations on travellers to a country such as Malaya (a yellow fever receptive area) from endemic regions and measures are taken to prevent the importation of infected mosquitoes.

Because it is important that Malayans should not have confused ideas about this important problem, I write to correct the statement by Hodder[1] that yellow fever is endemic in India and occurs in Malaya.

There is no evidence whatever that yellow fever has ever occurred in India, Malaya, or indeed anywhere in Asia. In fact serum surveys of man and animals in Malaya in this Institute,[2] and human serum studies in India[3] have failed to show the presence of antibodies to the yellow fever virus.

There is good evidence that yellow fever was carried from West Africa to South and Central America by the agency of man (probably in the slave traffic) and it has since become an enzootic disease of the forest and is almost certainly ineradicable in these regions. It is one of the great biological enigmas that yellow fever has not also been introduced to Asia from Africa as it has been shown that in South and South-East Asia there is no immunity in man or animals, and that local *Aedes* mosquitoes are excellent vectors of the disease.

1. B. W. Hodder, "Biogeographical aspects of settlement in Malaya," this *Journal*, vol. 5 (1955), p. 16.
2. *Federation of Malaya: Annual Report of the Institute for Medical Research for the year 1954* (Kuala Lumpur: in the Press).
3. W. A. Sawyer, J. H. Bauer and L. Whitman, "The distribution of yellow fever immunity in North America, Central America, the West Indies, Europe, Asia, and Australia, with special reference to the specificity of the protection test," *The American Journal of Tropical Medicine*, vol. 17 (Baltimore, 1937), pp. 137-61; and K. C. Smithburn, J. A. Kerr and P. B. Gatne, "Neutralizing antibodies against certain viruses in the sera of residents of India," *Journal of Immunology*, vol. 72 (Baltimore, 1954), pp. 248-57.

It is probable that if some traveller should reach Malaya unvaccinated, having been infected in an endemic area, and before the end of the incubation period of the disease (3-6 days), he might infect local mosquitoes and a great epidemic with many deaths might ensue. If the infection were carried to the animals of the forest, jungle yellow fever might be established and spread over the whole of South and South-East Asia. Public health precautions are taken to prevent this and research into the background and into control measures is being actively pursued.

I am, Sir,

Yours faithfully,
(Dr.) C.E. Gordon Smith,
Virus Research Officer.

The maps and diagrams in this volume have been drawn by Messrs. J. Ngai and Poon Puay-kee.

THE MALAYAN JOURNAL OF TROPICAL GEOGRAPHY

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